

March 2018

# On the Societal Impact of Self-Driving Trucks

Dylan Davitt Murray  
*Worcester Polytechnic Institute*

Eliot Moore Fine  
*Worcester Polytechnic Institute*

Justin Christopher Harris  
*Worcester Polytechnic Institute*

Follow this and additional works at: <https://digitalcommons.wpi.edu/iqp-all>

---

## Repository Citation

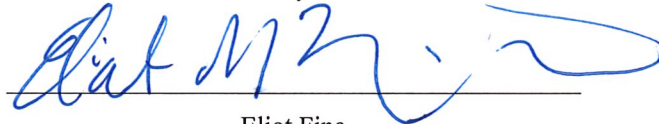
Murray, D. D., Fine, E. M., & Harris, J. C. (2018). *On the Societal Impact of Self-Driving Trucks*. Retrieved from <https://digitalcommons.wpi.edu/iqp-all/1768>

This Unrestricted is brought to you for free and open access by the Interactive Qualifying Projects at Digital WPI. It has been accepted for inclusion in Interactive Qualifying Projects (All Years) by an authorized administrator of Digital WPI. For more information, please contact [digitalwpi@wpi.edu](mailto:digitalwpi@wpi.edu).

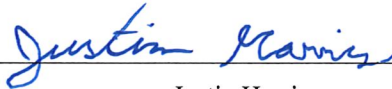
# On the Societal Impact of Self-Driving Trucks

An Interactive Qualifying Project Report  
Submitted to the Faculty of the  
WORCESTER POLYTECHNIC INSTITUTE  
in Partial Fulfillment of the Requirements for the  
Degree of Bachelor of Science

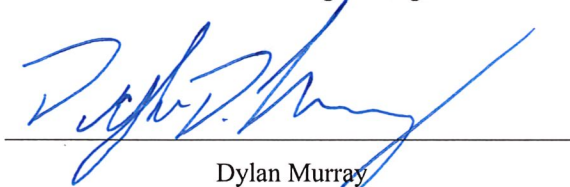
By



Eliot Fine  
Electrical & Computer Engineering



Justin Harris  
Mechanical Engineering



Dylan Murray  
Business Management



Approved by: \_\_\_\_\_

Prof. Raghvendra V. Cowlagi, Advisor  
Aerospace Engineering Program, Mechanical Engineering Department, WPI  
Prof. Alexander Wyglinski, co-Advisor  
Electrical & Computer Engineering Department, WPI

## **Abstract**

The objective of this project is to evaluate the state of the art and potential future impact of self-driving vehicles on the trucking and freight transportation industry in the United States. Specifically, the potential impact of self-driving semi-trailer trucks on the employment of truck drivers is studied. Current technology enables trucks to drive for long distances with little to no human supervision, and consequently, there are concerns about the erosion of truck driving jobs. This project postulates that self-driving technology is unlikely to cause a sharp decline in truck driving jobs in the near future. This postulate is based on observations of historic trends in the airline industry, in farming, and in personal banking. This project further postulates that the federal government must play a leading role in shaping policy for self-driving trucks to ensure consistency in regulations on self-driving trucks across states.

## Authorship Page

Section	Author	Project Work
<b>Abstract</b>		N/A
<b>1 Introduction</b>	JH	JH, EF, DM
<b>2 Background</b>		
2.1 Current Landscape of the Trucking Industry		
2.1.1 Local Versus Long Distance Trucking	DM	DM
2.1.2 The Trucking Industry at a Glance	DM	DM
2.1.3 Products and Market Breakdown	DM	DM
2.1.4 Cost Structures of Local and Long-Distance Trucking	DM	DM
2.2 Autonomous Vehicles		
2.2.1 Automation Terminology	JH, EF	JH
2.2.2 Autonomous Vehicle Technologies, in Brief	JH	JH
2.2.3 Current Examples of Autonomous Trucks	DM	DM
2.2.4 Potential Cost Breakdown for Self Driving Trucks	DM	DM
<b>3 Research Questions</b>		
3.1 Business & Consumer Impact	EF	DM
3.2 Impact on the Trucking Industry Workforce	EF	EF, JH
3.3 Expected Timeline of AV Adoption in Trucking	EF	JH, DM, EF
3.4 Government Involvement in AV Trucking	EF	EF
3.5 Parallel Industries & Trends	EF	JH, EF

<b>4 Methodology &amp; Findings</b>		
4.1 Employment in the Trucking Industry	EF	EF
4.2 Government Involvement in Autonomous Vehicles	EF	EF
4.3 Examination of Other Industries		
4.3.1 Autonomy in Airlines	JH, EF	JH, EF
4.3.2 Autonomy in Farming Vehicles	EF	EF
<b>5 Discussion &amp; Analysis of Results</b>		
5.1 The Threat of Job Loss Due to Autonomous Trucks		
5.1.1 Possibility of Trucker Layoffs is Legitimate	EF	EF
5.1.2 Hope for Sustained Trucker Employment	EF, JH	EF, JH
5.2 The Role of the Federal Government	EF	EF
<b>6 Conclusion &amp; Future Work</b>		
6.1 Summary of Findings and Analysis	DM	N/A
6.2 Project Success with Respect to Research Goals	JH	N/A
6.3 Project Difficulties & Sources of Error	JH	N/A
6.4 Next Steps	JH	N/A

# Table of Contents

<b>1 Introduction</b>	<b>6</b>
<b>2 Background</b>	<b>8</b>
2.1 Current Landscape of the Trucking Industry	8
2.1.1 Local Versus Long Distance Trucking	8
2.1.2 The Trucking Industry at a Glance	8
2.1.3 Products and Market Breakdown	10
2.1.4 Cost Structures of Local and Long-Distance Trucking	13
2.2 Autonomous Vehicles	15
2.2.1 Automation Terminology	15
2.2.2 Autonomous Vehicle Technology, in Brief	16
2.2.3 Current Examples of Autonomous Trucks	18
2.2.4 Potential Cost Breakdown for Self Driving Trucks	19
<b>3 Research Questions</b>	<b>21</b>
3.1 Business & Consumer Impact	21
3.2 Impact on the Trucking Industry Workforce	21
3.3 Expected Timeline of AV Adoption in Trucking	22
3.4 Government Involvement in AV Trucking	22
3.5 Parallel Industries & Trends	23
<b>4 Methodology &amp; Findings</b>	<b>24</b>
4.1 Employment in the Trucking Industry	24
4.2 Government Involvement in Autonomous Vehicles	29
4.3 Examination of Other Industries	31
4.3.1 Autonomy in Airlines	31
4.3.2 Autonomy in Farming Vehicles	36
<b>5 Discussion and Analysis of Results</b>	<b>40</b>
5.1 The Threat of Job Loss Due to Autonomous Trucks	40
5.1.1 Possibility of Trucker Layoffs is Legitimate	40
5.1.2 Hope for Sustained Trucker Employment	41
5.2 The Role of the Federal Government	48
<b>6 Conclusion and Future Work</b>	<b>50</b>
6.1 Summary of Findings and Analysis	50
6.2 Project Success with Respect to Research Goals	53
6.3 Project Difficulties & Sources of Error	53
6.4 Next Steps	54

<b>7 Works Cited</b>	<b>56</b>
<b>8 Appendices</b>	<b>63</b>
8.1 Appendix A: Complete Bibliography	63

# 1 Introduction

Improvements in safety and efficiency in vehicles has been a desired trend put forth around the world, with the latest frontier spearheaded in transport technology being that of autonomous vehicles, or AVs. AVs possess the potential to disrupt the ways in which we travel in the United States, while simultaneously reaching new standards of safety and fuel savings that have always been desired. It has been said by the IIHS (2015) that self-driving vehicles could prevent millions of crashes annually, while making air cleaner through estimated fuel economy increases of 15% (Heutger, Kückelhaus, 2014) While there are a multitude of benefits to this up and coming technology, there are also downsides. The current scope of concern is largely related to how automation in the near future has the potential to overtake a plethora of jobs and place many around the country into unemployment. The transport industry and its employees have relied on how motor vehicles typically operate for decades, and may not be prepared for the radical changes soon taking place.

Despite AVs reducing many of the causes for accidents and inefficient fuel usage, it is evident that large swaths of jobs and businesses in the transport industry will be negatively impacted. This includes the businesses and people focused on the effects of a country reliant on transport. Many industries are threatened by rates of increased safety from AVs alone. Approximately 90% of the crashes in the U.S. are caused by errors AVs will rarely make, if ever. The auto repair industry making nearly \$30 billion in auto repair revenue in 2013 could face losses of \$7.4 billion if autonomy prevented just a quarter of U.S. crashes, and \$27 billion if a crash reduction of 90% occurs annually (Clements & Kockelman, 2017). Another industry with potentially crippling losses is the medical industry, which had approximately \$23 billion in revenue due to motor accidents (NHTSA,



2015). Additionally, a significant margin of donor organs come from these occurrences. It is clear that while AVs improve on the function of transportation itself, industries directly and indirectly linked to transport may not be capable of remaining stable under this technology's propagation.

In addition to businesses being severely affected by self-driving vehicles, many employees of transport industries have a high risk of unemployment as their companies adapt to a changing autonomous landscape. However the benefits and detriments of this oncoming technology have mainly been evaluated from a passenger transportation standpoint, and has thusly neglected how America's road freight industry will react and adapt to this revolutionary change. Trucks are the bloodline of an industry that has brought in \$184.7 billion dollars of revenue in a recent year while employing over 1.7 million drivers (Bureau of Labor Statistics, 2016). Currently, no federal legislation has been put into action for autonomous trucks, yet there are a plethora of testing guidelines as well as laws being developed for passenger vehicles (Thune & Peters, 2017). This report will evaluate the impact autonomy will have on the trucking industry, and what shipping businesses, legislators, and truckers should expect and prepare for as trucks adopt this technology.

## **2 Background**

### **2.1 Current Landscape of the Trucking Industry**

One major aspect of our project is looking at the overall economic or business impact these new AV's will have on the trucking industry.

However, before we can understand the impacts these new AV's will have we first must understand how the trucking industry works and what creates change within that industry. Specifically, who is involved, how the industry is performing, what the costs and savings are, and what the potential outlook is for this industry and its businesses. In this section we will examine these different aspects of the trucking industry as well as look at the potential impacts these new self driving vehicles may have.

#### **2.1.1 Local Versus Long Distance Trucking**

There are two main forms of trucking companies, local and long distance. The only difference between the two types is how far each of them travel to bring their freight to its destination. Local trucking companies tend to deliver freight either over short distances within a metropolitan area or possibly across state lines typically taking trips that return the same day as delivery (Rivera, 2017a). Whereas for long-distance trucking, companies instead take freight from one metro area and bring it to another (Rivera, 2017b). Long distance trucking companies also move freight across national borders bringing goods to both Canada and Mexico as needed (Rivera, 2017b).

#### **2.1.2 The Trucking Industry at a Glance**

Next this report will look at the recent economic and financial state of the trucking industry. Specifically this report will look at the current state of both local and long-distance trucking in order to show any differences there may be between the two.

Long-distance trucking has seen relatively steady revenue growth since the 2008 recession with a growth rate of 1.1% since 2012 and an estimated growth of 1.4% from this year until 2022 (Rivera, 2017a). A possible reason for this growth is as consumer conditions have improved since the 2008 recession there has also been an increase in both trade volume as well as over all growth in industrial production, leading to an increased need to transport goods over long distances. This year the industry has brought in about \$184.7 billion in revenue with about \$10.7 billion as profit and \$48.0 billion going towards wages. The industry also has currently around 389,157 total businesses in operation in the United States (Rivera, 2017a).

The increase in industrial production is important to note because it represents the overall health and total growth of the manufacturing sector of the economy (Rivera, 2017a). As manufacturing output increases the demand for long-distance freight trucking increases as well due to manufacturing companies needing to move more of their products (Rivera, 2017a; Rivera, 2017b).

Another important part of the long-distance trucking industry is the use of fuel to run the freight trucks. This is because since 2013 diesel fuel prices have dropped leading to a negative effect on companies revenues because companies cannot charge a high surcharge to customers for the expensive fuel being used by the trucks. With this decline in surcharges companies have seen larger profit margins but low revenue growth. This loss however has been relatively countered by the increases in per capita income since the 2008 recession. This increase leads to more consumer spending and in turn increases demand for long-distance trucking in order for companies to keep up with the demand of consumers. Furthermore with the increase in profit margins companies have been forced to offer competitive wages and benefits in order to retain the best employees (Rivera, 2017b).

The local freight trucking industry has experienced many of the same things the long-distance freight trucking industry has. Such as similar revenue growth since the recession averaging about 2.1% annually since 2012 and is projected to grow annually by 2.4% from now until 2022. According to the source we obtained this information from, they predict that in 2017 alone this industry had a 9.3% revenue growth (Rivera, 2017b).

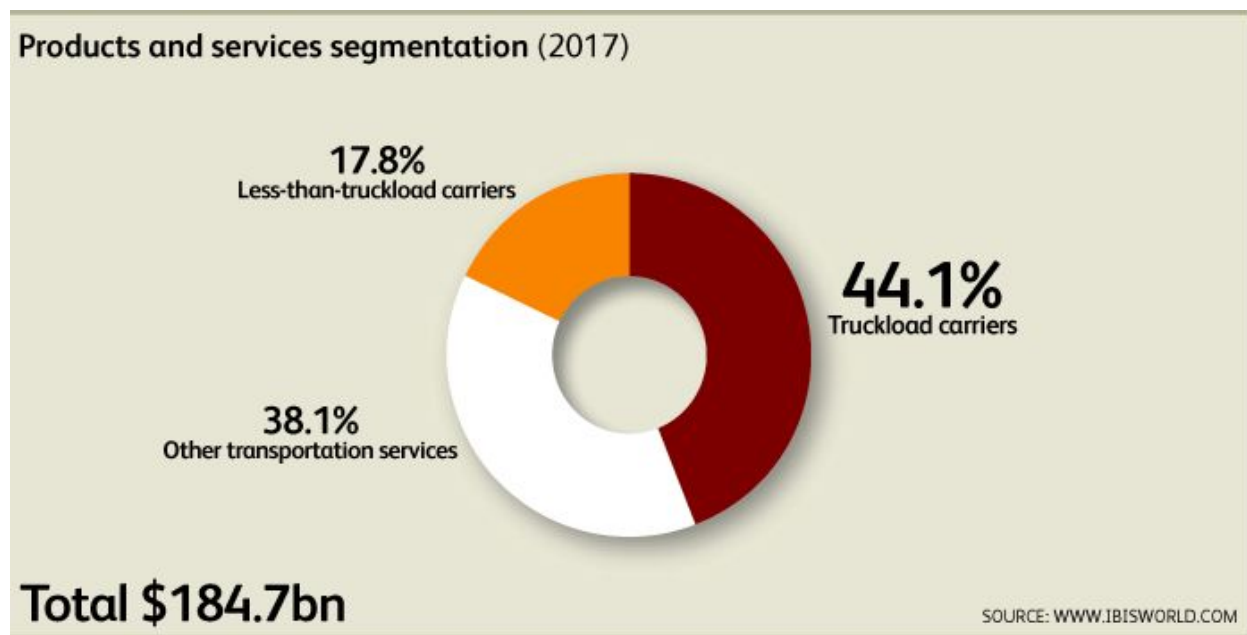
The local freight trucking industry has also seen the same impact from shrinking diesel fuel prices on their revenue but as with the long-distance trucking companies, local companies have been able to counter low fuel prices with rising disposable income and an increase in demand for the transportation of goods. This year local trucking companies have brought in about \$44.3 billion in revenue with \$3.0 billion in profit and \$14.2 billion going towards wages. The local trucking industry also has about 214,797 businesses in operation around the United States (Rivera, 2017b).

### **2.1.3 Products and Market Breakdown**

Both industries have identical supply chains that include auto part dealers, fuel or gasoline wholesalers, tire dealers, and truck or bus manufacturers. All these different sectors sell products or services to both trucking industries to allow them to function properly. Both industries also have similar areas they provide their services for including, construction, manufacturing, wholesale stores, as well as retail stores (Rivera, 2017a; Rivera, 2017b).

There are also different ways in which these two industries transport goods around. For long-distance trucking companies there are two main ways in which they deliver goods, the first is called truckload carriers and the second is known as less-than-truckload carriers. The former being the most prevalent in the long-distance trucking industry including around 80.4% of total long-distance trucking establishments and accounting for

about 44.1% of the revenue in the industry. The latter, less-than-truckload carriers or LTL only accounts for about 17.1% of total industry revenue. The main difference between the two forms are, truckload carriers fill an entire truck with goods and deliver all those goods to where they need to go whereas LTL carriers fill a truck with partial loads from multiple people then route the freight through a series of terminals where the freight is then transferred to other trucks who bring the goods to their destination. Aside from these two ways Long distance trucking companies also perform other services such as logistics, packaging, and customs brokerage which account for about 38.1% of the industries revenue (Rivera, 2017b).

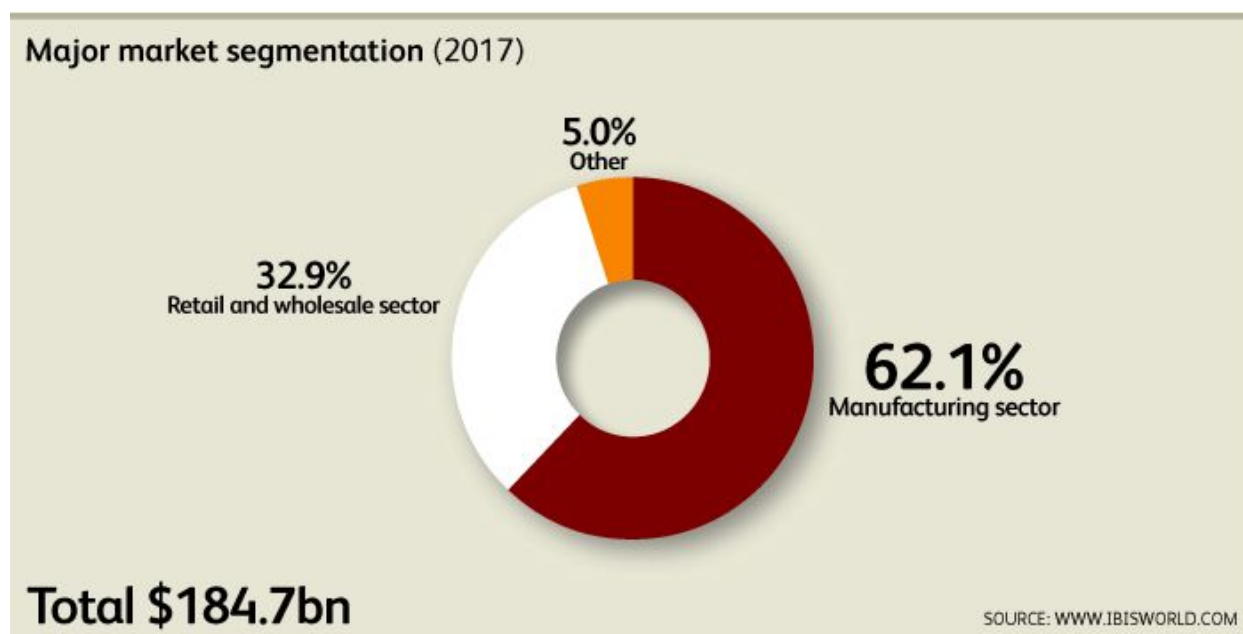


*Figure 2.1.3a— Long Distance Trucking Revenue*

Following the recession in 2008 demand for long-distance trucking went down dramatically. This was due mainly to a lack of disposable income for consumers. This lack of spending in turn reduced the total amount of freight that needed to be moved by trucking companies. This is the same for both the construction and manufacturing industries who rely heavily on demand from consumers with disposable income to buy products or build

houses. Since this no longer was happening there was no need for raw materials to be shipped by truckers. Other factors that directly affect long-distance trucking demand in the same way disposable income does are interest rates and taxes (Rivera, 2017b).

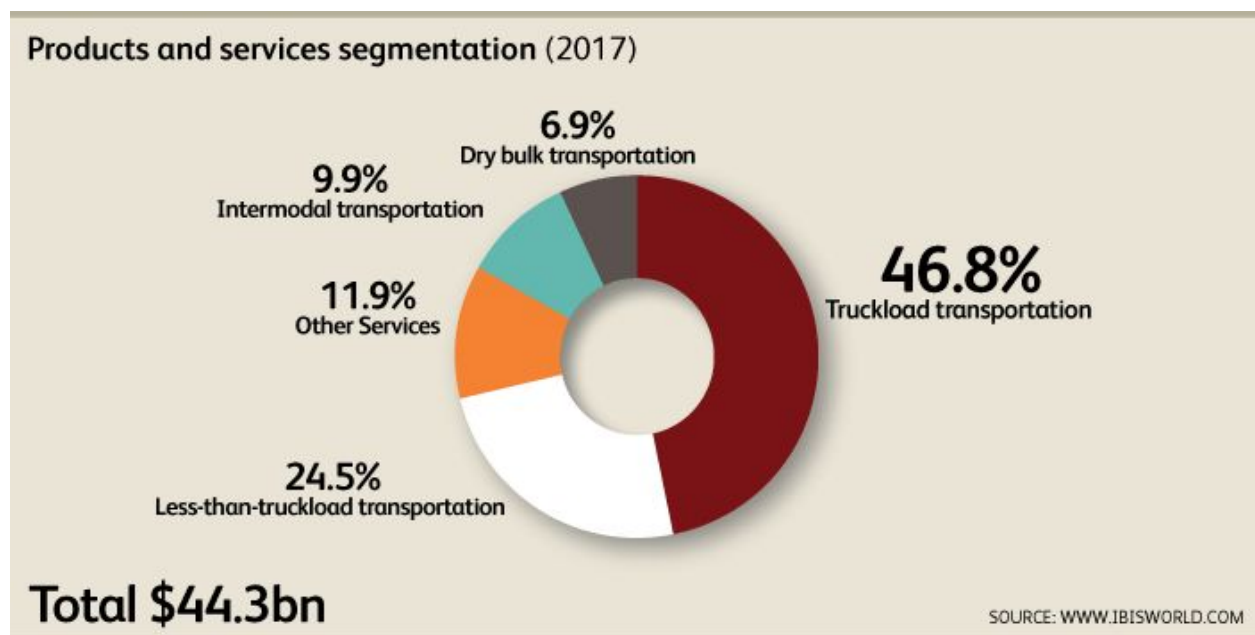
There are two main markets the long-distance trucking industry services, the manufacturing sector and the retail and wholesale sector. There are also other smaller things the long-distance trucking industry provides such as helping to move military consumables such as machinery or stationary. The amount the long-distance trucking industry services each market can be seen below (Rivera, 2017b).



*Figure 2.1.3b— Major Long Distance Trucking Service Markets*

“The geographical distribution of industry establishments largely reflects the industrial and agricultural output spread of the area. The high proportion of establishments in the Great Lakes, Southeast and Plains regions reflect greater output from industrial, manufacturing and agricultural production, respectively. Additionally, because Chicago is a land transportation hub for Asian imports, there is a sizable percentage of establishments in the Great Lakes region. The Great Lakes, Southeast and

Plains regions account for 24.3%, 24.1% and 11.1% of establishments, respectively” (Rivera, 2017b). As was stated earlier both the long-distance and local trucking industries have similar supply chains as well as markets which they service. The only differences between the two industries are local trucking companies perform two more services than long-distance trucking does, Intermodal and dry-bulk transportation which deals with things such as coal, iron, and grain (Rivera, 2017a; Rivera, 2017b).



*Figure 2.1.3c— Major Local Trucking Service Markets*

In terms of demand for local trucking versus long-distance trucking the determinants are largely the same. They depend on consumers disposable income and the need by retailers, manufacturers, and construction companies to move materials around (Rivera, 2017a; Rivera, 2017b).

#### **2.1.4 Cost Structures of Local and Long-Distance Trucking**

This report will now look at the different costs that come with operating and maintaining an average long distance or local trucking business. The costs that come with these businesses can be broken down into two main groups, vehicle-based and driver-based.

Vehicle based costs include, fuel, purchase payments for trucks, repair/maintenance, truck insurance costs, permits/licenses, and tolls. Driver-based costs include only wages and benefits for drivers. Below we can see a more detailed costs breakdown by average marginal costs per mile as well as average marginal costs per hour for trucking companies.

<b>Motor Carrier Costs</b>	<b>2008</b>	<b>2009</b>	<b>2010</b>	<b>2011</b>	<b>2012</b>	<b>2013</b>
<i>Vehicle-based</i>						
Fuel Costs	\$0.633	\$0.405	\$0.486	\$0.590	\$0.641	\$0.645
Truck/Trailer Lease or Purchase Payments	\$0.213	\$0.257	\$0.184	\$0.189	\$0.174	\$0.163
Repair & Maintenance	\$0.103	\$0.123	\$0.124	\$0.152	\$0.138	\$0.148
Truck Insurance Premiums	\$0.055	\$0.054	\$0.059	\$0.067	\$0.063	\$0.064
Permits and Licenses	\$0.016	\$0.029	\$0.040	\$0.038	\$0.022	\$0.026
Tires	\$0.030	\$0.029	\$0.035	\$0.042	\$0.044	\$0.041
Tolls	\$0.024	\$0.024	\$0.012	\$0.017	\$0.019	\$0.019
<i>Driver-based</i>						
Driver Wages	\$0.435	\$0.403	\$0.446	\$0.460	\$0.417	\$0.440
Driver Benefits	\$0.144	\$0.128	\$0.162	\$0.151	\$0.116	\$0.129
<b>TOTAL</b>	<b>\$1.653</b>	<b>\$1.451</b>	<b>\$1.548</b>	<b>\$1.706</b>	<b>\$1.633</b>	<b>\$1.676</b>

*Figure 2.1.4a— Average Marginal Costs Per mile, 2008-2013 (Torrey & Murray, 2014)*

<b>Motor Carrier Costs</b>	<b>2008</b>	<b>2009</b>	<b>2010</b>	<b>2011</b>	<b>2012</b>	<b>2013</b>
<i>Vehicle-based</i>						
Fuel Costs	\$25.30	\$16.17	\$19.41	\$23.58	\$25.63	\$25.78
Truck/Trailer Lease or Purchase Payments	\$8.52	\$10.28	\$7.37	\$7.55	\$6.94	\$6.52
Repair & Maintenance	\$4.11	\$4.90	\$4.97	\$6.07	\$5.52	\$5.92
Truck Insurance Premiums	\$2.22	\$2.15	\$2.35	\$2.67	\$2.51	\$2.57
Permits and Licenses	\$0.62	\$1.15	\$1.60	\$1.53	\$0.88	\$1.04
Tires	\$1.20	\$1.14	\$1.42	\$1.67	\$1.76	\$1.65
Tolls	\$0.95	\$0.98	\$0.49	\$0.69	\$0.74	\$0.77
<i>Driver-based</i>						
Driver Wages	\$17.38	\$16.12	\$17.83	\$18.39	\$16.67	\$17.60
Driver Benefits	\$5.77	\$5.11	\$6.47	\$6.05	\$4.64	\$5.16
<b>TOTAL</b>	<b>\$66.07</b>	<b>\$58.00</b>	<b>\$61.90</b>	<b>\$68.21</b>	<b>\$65.29</b>	<b>\$67.00</b>

*Figure 2.1.4b— Average Marginal Costs Per Hour, 2008-2013 (Torrey & Murray, 2014)*

In the same study this data was found they also broke down the average total marginal costs for less-than-truckload carriers, specialized carriers, and truckload carriers.

<b>Sector</b>	<b>2008</b>	<b>2009</b>	<b>2010</b>	<b>2011</b>	<b>2012</b>	<b>2013</b>
LTL	\$1.81	\$1.43	\$1.76	\$1.93	\$1.79	\$1.84
Specialized	\$1.87	\$1.67	\$1.61	\$1.79	\$1.73	\$1.67
TL	\$1.48	\$1.36	\$1.43	\$1.57	\$1.51	\$1.60

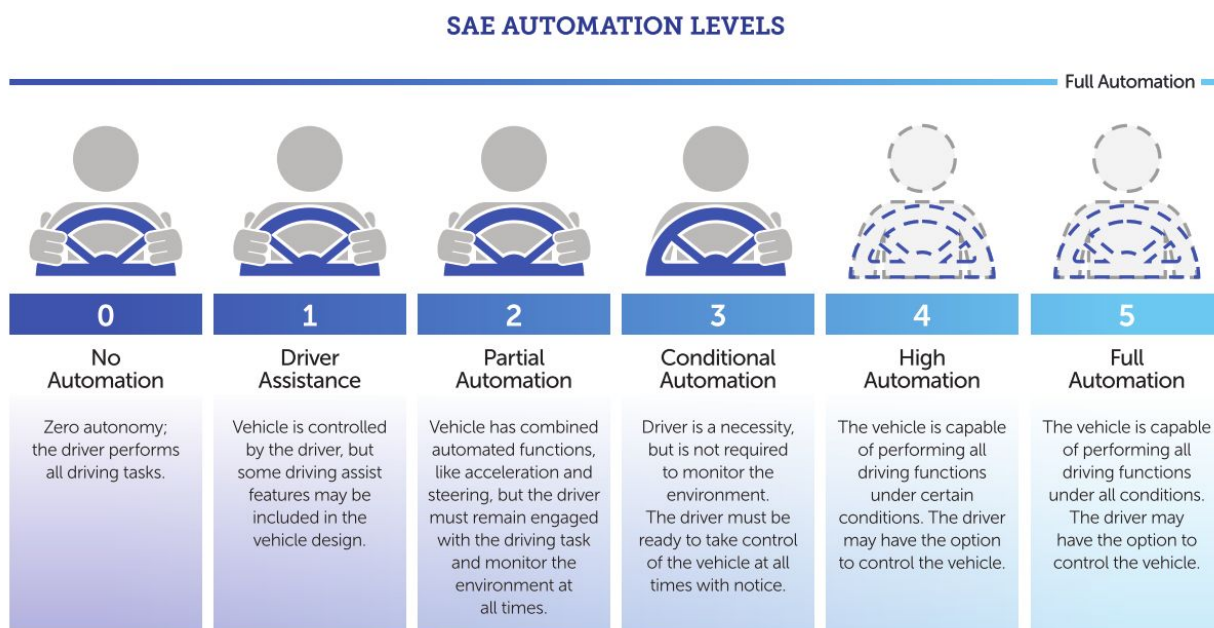
*Figure 2.1.4c— Average Total Marginal Costs by Sector, 2008-2013 (Torrey & Murray, 2014)*



## 2.2 Autonomous Vehicles

Autonomous vehicles, although intricate in function, revolve around improving the overall performance of basic tasks when compared to a human driver. Many automotive and tech companies in recent years have hastened development of self-driving technology, yet it is clear through the varying approaches and plentiful testing presently occurring in the U.S. that there is still much development work to be done. Nonetheless, standards for what an autonomous vehicle is and the means in which it operates do exist, and will be explained in order to understand the benefits and drawbacks the technology will have on the trucking profession.

### 2.2.1 Automation Terminology



*Figure 2.2.1a— Automation levels in vehicles (NHTSA, 2017)*

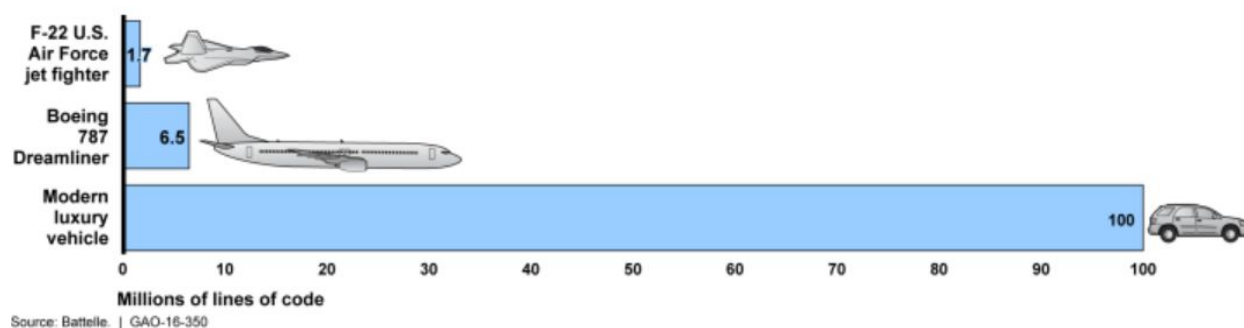
The National Highway Traffic Safety Administration has based its criteria for autonomous vehicles on the ranking system conceived by the Society of Automotive Engineers, as seen above. Nearly all motor vehicles in the present day have been at Level 0

autonomy, being fully controlled by a human driver, while levels 1 through 3 have gained widespread traction through recent years. Cruise control, parking assistance, lane departure and forward collision warnings, and blind spot detection are some of the technological thresholds found within these levels to give a vehicle certain qualifications. In fact, installing semi-autonomous technologies of these on all U.S. passenger vehicles could prevent an estimated 1.9 million crashes annually (Highway Loss Data Institute, 2010). Greater safety could thusly be achieved if the same were done at Level 4 or 5 automation, not to mention the potential fuel savings and smooth traffic flow autonomous technology could bring. Simultaneously, the lack of human input within these two levels pose the biggest threat to the over 1.7 million truck drivers in the U.S., and will be the main focus of this evaluation (Bureau of Labor Statistics, 2016).

### **2.2.2 Autonomous Vehicle Technology, in Brief**

Level 4 and 5 autonomous vehicles rely on a suite of sensors, systems, and code in order to operate in a vigilant and attentive manner without driver input. Most of these systems exceed the capabilities of human sensory function, thus leading to the drastic increase in safety expected when these vehicles become mainstream. One of these sensory advantages comes in the vision of AVs. LIDAR, or light detection and ranging, is the vital vision system for the most advanced level 5 vehicles today. Typically placed on the top of a vehicle for the best vantage point, LIDAR can provide 360 degree scans of the environment while measuring distances of nearby objects within 2 cm of accuracy (Cameron, 2017). These three dimensional scans provide information which informs the vehicle's computers of where things are relative to it, while cameras and radar assist in identifying what those objects potentially are.

The job of an AV's on board computer systems is to interpret the information given by cameras and LIDAR, and utilize that data complete tasks. Maintaining a lane on the road, keeping up with traffic, or developing a response to avoid a collision act as examples of this information in use. This takes inspiration from the sense-plan-act design that most robotic systems rely on, allowing Google to achieve 500,000 miles of autonomous road use without an accident at the fault of the AV (RAND, 2016). The system will sense for example an impending object with its sensory suites, plan a correct maneuver to avoid the object, and then command the motors controlling the movement of the vehicle to act out that plan. These systems must not only keep track of a cars surroundings, but maintain the proper routes on the way to a destination using GPS. Internal navigation systems are also relied on to maintain a course in case GPS accuracy is hindered. This goes without mentioning the advancements of artificial intelligence within AVs, with many companies developing digital maps of roadways in order to familiarize a self-driving vehicle with terrain it may not have ever physically travelled before. While it may be a triumph for computerized AVs to maintain above human level vigilance at all times without fatigue, these complex systems do come with drawbacks.



*Figure 2.2.2a Average Lines of Software Code in Modern Luxury Vehicle Compared to Types of Aircraft (Wise, 2016)*

Despite the constant awareness an autonomous system provides, the complexity of AVs widens the margins for error and misinterpretation of information. As shown in the

figure above, a modern luxury vehicle vastly exceeds the amount of coding found in a modern passenger jet. Coding errors and other vulnerabilities of AVs will only grow, as the lines of code within them are expected to rise in quantity as technologies advance (Wise, 2016). Self-driving vehicles require a level of awareness different from that of a jet due to the constant presence of objects around them. Considering the autopilot of today's aircraft must still rely on human operation due to both human and computerized mistakes, it can be difficult to argue that the same precautions shouldn't initially be taken for the first generations of mainstream autonomous trucks.

### **2.2.3 Current Examples of Autonomous Trucks**

In recent years and as self driving technology has advanced automotive/tech companies such as Daimler, Uber/Otto, Volvo, Embark, and Google's' Waymo have been conducting trial runs of self driving trucks in the United States and Asia in order to further advance the capabilities of self driving tractor trailers. In the following examples below we will see that as far as the technology has come, it is still in its beginning stages and possibly years away from being implemented in the real world and on real roads .

Nevertheless a recent milestone for self driving trucks came In May 2015 when a self driving Freightliner inspiration truck made by Daimler Trucks North America (DTNA) was granted the first ever license by the state of Nevada for a self driving truck to operate on state highways ("Freightliner Inspiration," 2015). The truck was only shown to move forward on a closed track but still showcased the potential for further improvement. Then just two years later in February 2017 a "Volvo tractor-trailer equipped with radar and laser-based sensors, cameras, and software developed by San Francisco-based Otto" completed the task of bringing 2,000 cases of Budweiser beer on a 120 mile trip down a colorado highway, without a driver (Degan, 2017).

Later in November 2017 Volvo itself demonstrated in Beijing, China at the Volvo Group innovation summit a new self driving truck that was designed to travel within areas such as harbors and dedicated highways “for hub-to-hub transportation in semi-confined areas” (HDT, 2017). Like many other self driving trucks and vehicles this tractor trailer used both “lidar and GPS to continuously scan its surroundings and check its location” (HDT, 2017). Earlier this year in February 2018 a startup called Embark completed a test run of a modified Peterbilt tractor that was equipped with its own autonomous software and a group of sensors that allowed it to travel from Los Angeles, California to Jacksonville, Florida (Clevenger, 2018). The tractor trailer was operating under level 2 vehicle automation and had a driver present in case they needed to take over for any reason. Next, a month later in March 2018 Uber revealed that over the past few months it has been using its own self driving trucks on Arizona Highways to deliver cargo for commercial freight customers (Wakabayashi, 2018). Uber's fleet is self driving but still uses drivers behind the wheel in case a human needs to take control of the vehicle at any moment. Finally days later in March 2018 Google's Waymo began using its own self driving trucks in Atlanta, Georgia to bring cargo to Google's data centers also still using a driver behind the wheel in case of emergency (Holley, 2018).

These few examples show just how far the technology of self driving trucks has come, but also shows there is still much to be done if companies wish to achieve their goal of reaching vehicle automation level four to five.

#### **2.2.4 Potential Cost Breakdown for Self Driving Trucks**

It is obvious to assume that once self driving technology for trucks becomes available to the public the price of a self driving truck will be much greater than the price of a regular truck nowadays. Since there is currently no commercial systems available to purchase we

have had to rely entirely on estimates we find within studies and articles. According to a 2016 American Transportation Research Institute (ATRI) study on the potential impacts of self driving trucks they estimated that a truck such as the one described earlier made by Otto, now Uber would cost \$30,000 per truck to make it self driving (Short & Murray, 2016). They also broke down the potential costs of self driving truck hardware by automation levels, estimating a level 3 automation upgrade would cost \$13,100, level 4 costing \$19,000, and level 5 costing \$23,400 (Short & Murray, 2016). “These costs are mainly related to software, and do not include inspection, maintenance or updates” which could potentially increase these costs (Short & Murray, 2016).

Aside from the potential costs associated with making trucks self driving there are also potential benefits as well. In a study which analyzed the potential costs of ownership for self driving vehicles they found that the total operating costs (TCO) of a 7.5 ton truck could see a decrease of 22.6%, an 18 ton truck could see a 19.5% decrease, and a 38 ton truck could potentially see a 15.0% decrease in its TCO (Wadud, 2017).

## **3 Research Questions**

### **3.1 Business & Consumer Impact**

We intended to examine the financial effects of autonomous trucking. This began with research in the current state of the trucking industry as well as an examination of the likely cost increases associated with autonomous cars and trucks, From there, what financial predictions can we make regarding costs & savings for companies that ship their products by truck, by switching to AV's? There will likely be some up-front costs with deploying autonomous trucks; will the efficiency brought by this change be enough to offset the costs of purchasing and maintaining these high-tech vehicles? Can we estimate a timeline for this cost savings based on previous models?

More specifically, will there be a cost savings at Level 4 autonomy? Or, will the payroll of the driver need to be dropped in order to offset the cost of autonomous trucks. Essentially, will people need to be laid off in order to make this financially feasible?

Can we expect to see benefits passed on to consumers? Will shipping costs be reduced, or will consumers be able to get goods shipped to them faster, or in more remote areas of the country?

Ultimately, only a portion of these questions were answered in full, due to limited time and limited data. Neither autonomous vehicle manufacturers nor shipping companies were particularly willing to share their information on revenues and expenses.

### **3.2 Impact on the Trucking Industry Workforce**

We set out to examine the ways in which the rise of autonomous vehicles will affect employees of the trucking freight industry, specifically those semi-trailer drivers

themselves. Can we prove that the rise of autonomy in trucks will not have a profoundly negative effect on employment of truckers?

Specifically, will we see changes in available jobs, salaries and job descriptions? Will truckers need to learn new skills in order to be an effective employee in this new environment? Level 4 autonomy is designed to make driving easier and safer. Is it fair to say that drivers might actually see an improvement in job satisfaction?

Additionally, is there evidence to suggest that automatization of trucks will stop at Level 4, at least for a while, requiring the coexistence of human driver and autonomous vehicle?

We were fairly successful in our findings in this region.

### **3.3 Expected Timeline of AV Adoption in Trucking**

We researched the anticipated timeline of autonomous technology adoption in the trucking industry. How soon can we expect to see each level of autonomy come to market? How soon can we expect to see autonomous freight vehicles actually deployed?

We found very little real data on this research question. What information there was entirely qualitative and vague, and came only from the personal opinions of industry experts, rather than any hard data or case studies. Ultimately, we decided that this question depended on too many variables that were challenging to predict and control, and therefore this question was slated for abandonment. Perhaps an economist could put together some sort of industry prediction model in order to make this forecast, but it felt more challenging than we had the capabilities and resources for.

### **3.4 Government Involvement in AV Trucking**

The federal government will play a major role in the rate of adoption of AV trucking, since federal regulations govern highway transportation, safety regulations and commerce.



What is the government's current involvement in the autonomous trucking industry? As of the fall of 2017, no federal regulations had been passed in regard to autonomous trucking. What else has been done, since then? What is in the works?

What does the federal government need to do to encourage the success of autonomous trucking? Do new regulations need to be put into place, and do some of the old driving regulations need to be abandoned?

What does the federal government need to do to ensure that employment of truckers is protected? And should they do anything?

This question could have almost been a separate paper, but we kept it in the fold as we felt that it was important, and because the conversation on autonomous trucking is so dependent on how they respond. We were able to address nearly all of these questions, although future research could explore some of them to a greater degree of depth,

### **3.5 Parallel Industries & Trends**

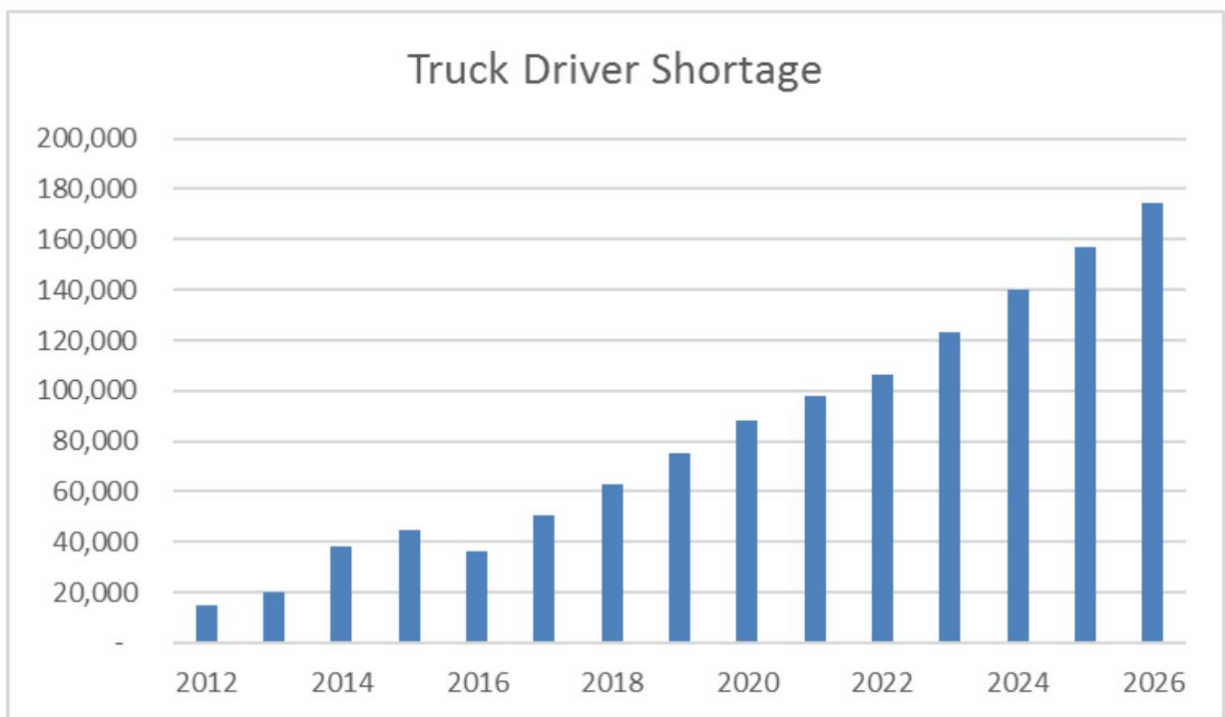
This question is sort of interwoven throughout the rest of the project. Because this project involves estimations and predictions for how the trucking industry will adapt to autonomous technology, trends in similar industries is a primary source of evidence-based backup for thesis points. Specifically, we asked, what happened to pilot employment in the airline industry when autopilot was introduced? Was there a change in number of pilots employed, job satisfaction or salary? Why hasn't the airline industry advanced to complete, level 5 autonomy? Additionally, what is happening to farm equipment operator employment, as they begin to adopt autonomous farming vehicles? Are there other industries where we can draw parallels?

This involved some digging into employment data archives which wasn't always fruitful. Ultimately, we saw reasonable success here but some things were left unanswered.

## 4 Methodology & Findings

### 4.1 Employment in the Trucking Industry

The trucking industry is facing a major shortage in employment. This employment shortage was first documented in 2005, at which time the shortage was approximately 20,000 jobs (Costello, 2017). In 2008, this shortage was erased as industry volumes dropped drastically; coinciding with the major US financial crisis of 2008 (Costello, 2017; Havemann, 2009). Shortage in employment grew again from there, up to roughly 45,000 jobs by 2015 (Costello, 2017). This issue isn't expected to go away—if current trends hold, this shortage could be over 174,000 by 2026 (Costello, 2017). Figure 4.1a, below, demonstrates the predicted job shortages in the trucking industry.



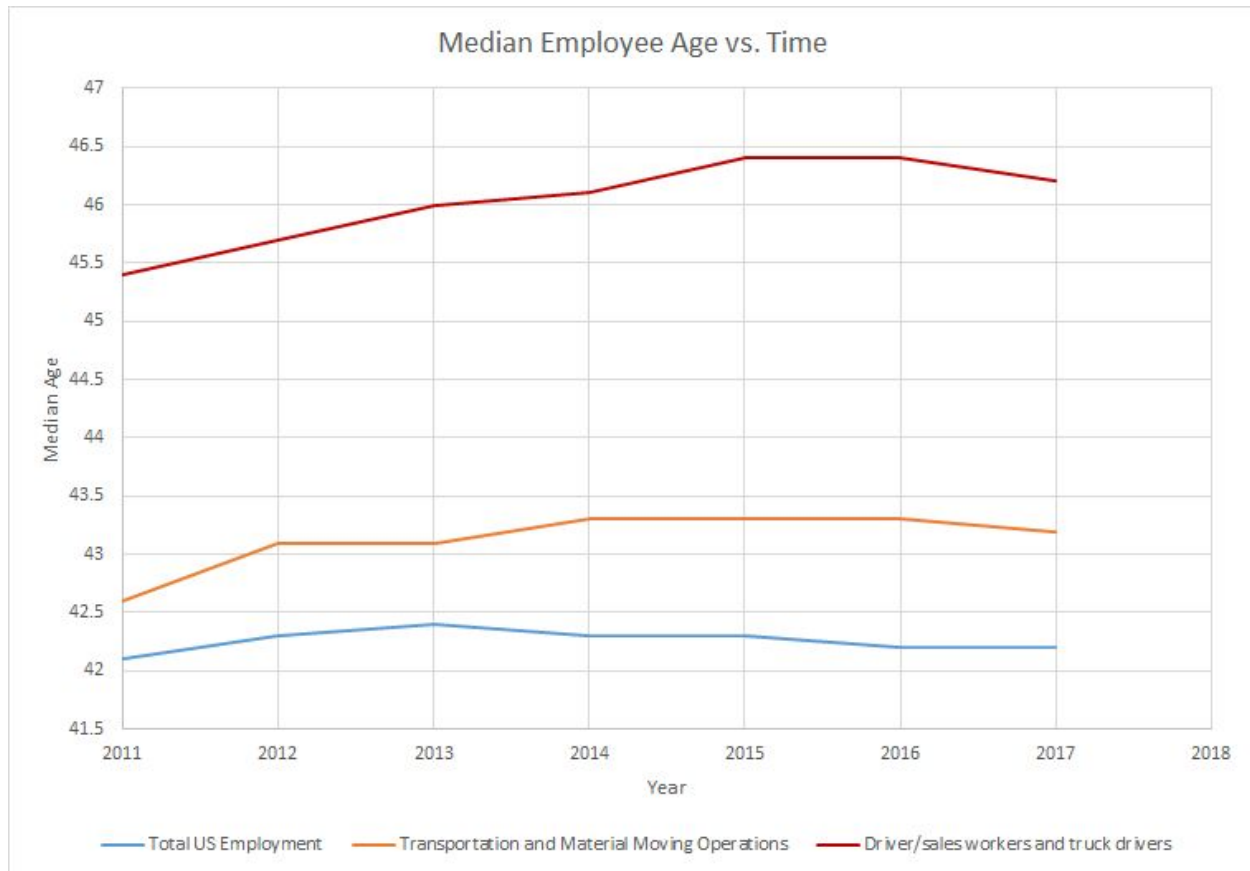
*Figure 4.1a— Truck Driver shortages from the years 2012 to 2017, and predicted shortages through the year 2026, based on the data provided by the American Trucking Associations' 2017 Truck Driver Shortage Analysis*

There are various reasons for this shortage. The limited demographic of truck drivers is an issue, as the industry has “historically struggled to attract all segments of the population” (Costello, 2017, p. 2). For example, in 2016 just six percent of truck drivers were women, and this is consistent with the past fifteen years (Costello, 2017). In comparison, women made up 46.78% percent of employed persons over the age of twenty in the year 2017, according to data the Bureau of Labor Statistics Data collected in 2017.

The American Trucking Associations (ATA) has also cited the lifestyle of the job as a root cause of the driver shortage (2017). Drivers are expected to spend long periods of time alone and away from home, and new drivers are designated especially taxing routes (Costello, 2017). The ATA suggests that other fields requiring similar education levels and skill sets are attracting would-be truck drivers (2017).

The semi-trailer truck driving is not necessarily a glamorous position. A 1998 study by Debby A. Renner, MS, RN, classified cross-country truck drivers as a “vulnerable population,” in that they are be highly susceptible to harm associated with “health risks, limited control, disenfranchisement, victimization, disadvantaged status, and powerlessness” (p. 164). There are clearly documented health risks for drivers, as studies have shown they tend not to perform regular exercise, smoke in high volumes and having a high body mass index (Renner, 1998). “Drivers reported being diagnosed with, in descending order: back injuries, hearing loss, hemorrhoids, hernias, and unspecified types of heart disease” (Renner, 1998, p. 165). Renner’s paper claims that drivers are at risk for a lack of emotional connection to mainstream society, due to their isolated role and time spent away from social support (1998). The ATA’s annual report cites the negative public perception of truck drivers as a contributor to this employment crisis.

Also, the trucking industry requires drivers to be over the age of 21, which may be limiting the number of young people finding a career in trucking, since “potential drivers are likely to have found another career path (that they are already three years into) by the time they reach 21” (Costello, 2017).

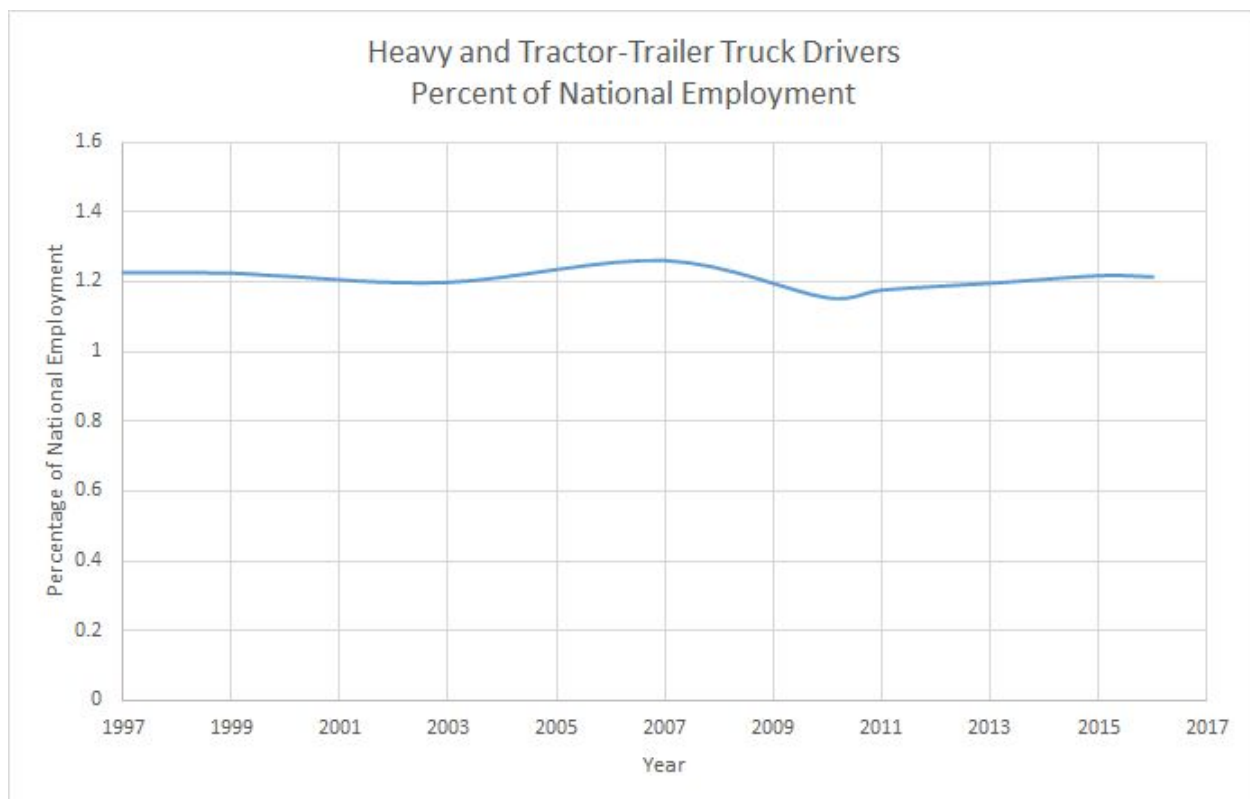


*Figure 4.1a— Median employee age versus time  
(Bureau of Labor Statistics, Current Population Survey, 2010-2017)*

The greatest contributor to this driver shortage is the high average age of the existing workforce. Figure 4.1a, below, shows the median age of the average employed person in the United States, and contrasts it with the median age of those working in the transportation industry, based on data gathered over the past seven years by the Bureau of Labor Statistics Current Population Survey. The national average for employment is shown in blue, and is consistently around 42.5%. All persons employed in in the “transportation

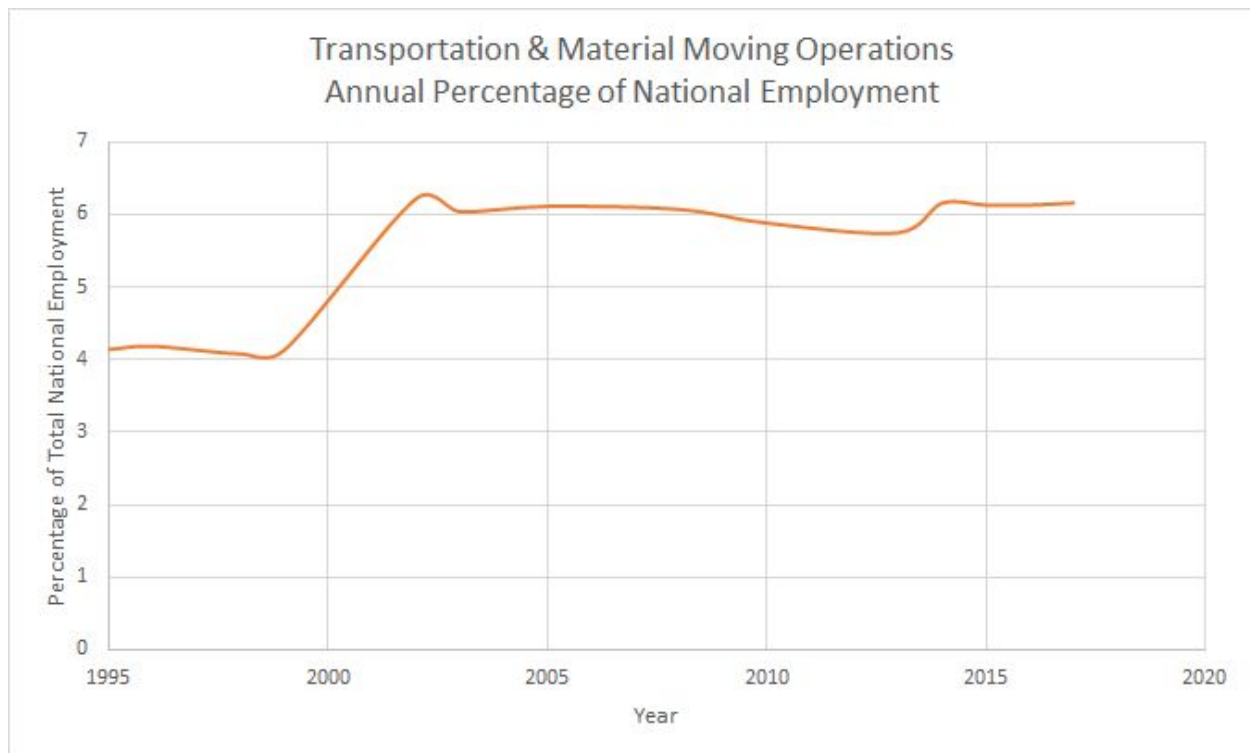
and material moving operations” industry, a rather broad category, are noted in blue, and are slightly higher than the national average, slightly above 43%. Those explicitly employed as “drivers/sales workers and truck drivers,” a subset of the aforementioned industry, are marked in red on the figure. The average age of employees in this category was 46.4% in 2017. And more specifically, according to surveys by the ATA, the average driver age in the “for-hire over-the-road truckload industry,” is 49 (Costello, 2017). Meanwhile, only 25.1 percent of the trucking workforce was under the age of 35 in 2017, compared to 35.0 percent of total employees nationally.

Drivers leaving due to retirement will be the greatest contributor to future driver demand. Forty-nine percent of future need will come from replacing retired drivers (Costello, 2017).



*Figure 4.1b— Truck Driver Employment Compared to National Employment*

When looking at employment of truck drivers compared to total employment nationwide, it has actually remained fairly consistent. We gathered data from the Bureau of Labor Statistics Occupational Employment Statistics reports over the past 20 years. The number of persons employed in the industry was compared to the number of persons employed nationwide, resulting in a percentage of national employment in the industry, and helping to control for inconsistencies in these surveys from year to year. We found that “Heavy and Tractor-Trailer Truck Drivers” maintained approximately 1.2% of total employment in the United States. Figure 4.1b, above, highlights the results of this data comparison.



*Figure 4.1c— Annual percentage of national employment for the transportation and material moving operations industry.*

We performed the same data analysis for those employed in transportation and material moving operations, the broader industry which contains semi-trailer truck driving, using data sets collected by the Bureau of Labor Statistics in their Current Population

Survey since the year 1995. The number of persons employed in the industry was compared to the number of persons employed nationwide, resulting in a percentage of national employment in the industry, and helping to control for inconsistencies in these surveys from year to year. Figure 4.1c, above, shows the results of this data comparison.

Our research for the background section of this report (Section 2) showed that the trucking industry has averaged positive growth over the past five years, and is expected to continue to grow at an even greater rate through the year 2022. Industry growth is expected to account for 28% of new driver hires over the next decade (Costello, 2017).

## **4.2 Government Involvement in Autonomous Vehicles**

The Department of Transportation’s National Highway Traffic Safety Administration (NHTSA), has released two policy frameworks regarding self-driving vehicles in the United States, one in 2016 and an updated version in 2017. Their mission was twofold, to encourage safety and provide an environment that encourages innovation.

*The Federal Government wants to ensure it does not impede progress with unnecessary or unintended barriers to innovation. Safety remains the number one priority for the U.S. Department of Transportation (DOT) and is the specific focus of the National Highway Traffic Safety Administration (NHTSA, 2017).*

However, these documents are a nonregulatory approach to governance on this issue. Information is divided into two sections: “Voluntary Guidance for Automated Driving Systems” which encourages particular practices of the automotive industry as they begin to design autonomous vehicle and “Technical Assistance to States, Best Practices for Legislature Regarding Automated Driving Systems” (NHTSA, 2017). As a nonbinding piece of government documentation, individual States have a good deal of freedom, and despite the guidelines set forth, it is possible that States will not adhere to the guidelines in the

creation of their own regulations on self-driving vehicles, or that they will not produce legislation at all, on the matter.

Testing of autonomous vehicles has been performed all over the country. The federal government established ten designated testing locations for autonomous vehicles, in nine different states (Hawkins, 2017). States have established their own programs for testing, as well. The Commonwealth of Massachusetts, for example, has set up a testing site at Fort Devens, and has established a legal process by which companies can apply to test their vehicle in the state, establishing a Memorandum of Understanding between the Massachusetts Department of Transportation, the municipality in which testing will occur, and the company testing the product (Fichter, 2017). Self-Driving trucks have been tested as well. In May of 2015, the state of Nevada granted the first license for an autonomous commercial truck to operate on an open public highway in the United States (*Freightliner Inspiration*, 2015).

In September of 2017, the House of Representatives unanimously approved a bill—called the SELF-DRIVE act—which opens up the field for innovation by allowing companies developing self-driving vehicles to bypass some of the requirements that currently apply to human-controlled vehicles (Etherington, 2017). This bill would have to be approved by the Senate to become law.

Neither of the NHTSA guidelines make mention of autonomous trucks, except to say that trucks are under the jurisdiction of the NHTSA and the Department of Transportation (NHTSA, 2017). The bill passed by the House of Representatives does not include autonomous trucks over 10,001 pounds (Thune & Peters, 2017)—part of the legal designation for a vehicle to be considered a commercial motor vehicle (Federal Motor Carrier Safety Administration, 2015). The Senate has discussed legislature on autonomous



trucks, but it is at this point unclear whether or not they will be a part of this first round of legislation (Thune & Peters, 2017).

Interstate commerce is a vital part of the trucking industry. Long-distance trucking, which is defined as delivering goods from one metro area to another, was a \$184.7 billion industry last year (Rivera, 2017a). The lifeblood of this industry is the ability to easily transport across the country, and for autonomous trucking to take hold, these vehicles must not face challenges complying with different regulations in different areas.

## **4.3 Examination of Other Industries**

### **4.3.1 Autonomy in Airlines**

Although fairly new in the aspect of road going vehicles, autonomy has already found its place in other forms of transportation. For the sake of truckers in the U.S., it proves useful to evaluate a similar field that has already gone through the autonomy process to see how trucking may be affected. Modern passenger jets are capable of near full autonomy, utilizing a pilot most frequently in emergency situations as well as takeoffs and landings. The main attribute of the technology is that it allows pilots focus on other activities while reducing pilot stress. Airline pilots have been on decline for a multitude of reasons besides autonomy however, such as the expensive barrier of entry, and the lack of interest in a job that requires long training sessions, and constant travel for hours straight. Despite this, pilots are in demand now more than ever. Many airlines look to increase wages and benefits in order to attract new trainees to replace those reaching the mandatory retirement age of 65 (Federal Aviation Administration, 2012). These reasons and more are why it is worthwhile to evaluate the impact autopilot has had on the commercial airline industry, so we may more accurately predict the changes that will be made once trucking autonomy becomes commonplace.

In order for the data of the airline industry to assist us in understanding how autonomous technology will affect the trucking industry, it is first important to know the basic history and function of autopilot. Autopilot is aviation's equivalent to the self-driving technology currently being developed for cars and trucks. Despite both forms of autonomous technology having roots in the early 1900s, the beginnings of autopilot gave way to broad implementation of the technology much earlier than ground based autonomous transport. Lawrence Sperry in 1914 had demonstrated the Sperry Gyroscope Company's device at the Aero Club of France's aero plane safety competition. Although there were many pursuing gyroscopic stability systems within aviation for nearly a decade at this point, Sperry's demonstration was the proof of concept that accelerated the growth of the new technology. Many witnessed the spectacle as Sperry flew by the crowd with his hands on his head, while his co-pilot/mechanic Emile Cachin walked on the wing of the vehicle, only for his weight to be countered by the system they developed (Scheck, 2017). It was a gyroscope which controlled the pitch and roll of the plane, mainly using pneumatic and mechanical systems to enact its balancing function. The device factored in airspeed, and contained a feedback mechanism that prevented over oscillation of the plane when the system was used. Although it wasn't the first autopilot conceptually, the Sperry Gyroscope Company's demonstration utilized the first plane to successfully stabilize itself with these concepts (Howard, 1973).

It wasn't long before Sperry's device was put into good use, as the first ever commercial operation of his company's autopilot system was in 1931, authorized to fly both passengers and mail by the U.S. Department of Commerce. The flight was successful, yet saw flaws in the system that caused the company to develop versions in which a pilot could disengage portions of programming as they wished, making the plane easier to fly under

certain actions and conditions. These advancements later led to long distance flight tests in 1933, such as Wiley Post's successful seven day flight across the world, as well as Floyd Bennett's 25,000 mile journey which also proved the merit of autopilot. These tests and more allowed autopilot to be broadly accepted in the 30s, as both commercial and military use of not only Sperry's gyroscopes, but those of competitors had propagated (Howard, 1973). The progress made in the coming decades would propel autopilot to a position in which nearly all state of the art aircraft would contain some semblance of the system in the present day.

Autopilot has made drastic advancements since one of its first demonstrations in 1914, and plays just as much of a vital aspect of flight now as it did then. The technology has improved, yet intentions of these devices have remained the same. Maintaining altitude, navigating the plane from programmed waypoints, and flying various approaches have been made precise through various sensors as well as GPS. Modern autopilot can be generalized into two main components, being the servos and circuitry controlling the panels and flaps that direct the plane, and the flight director (FD) as the control unit which views the actions and movements needed to complete a pre-programmed task. (Federal Aviation Administration, 2017)

Operation of autopilot systems can vary in function depending on the goals to be met, and it is up to the pilot to specify those parameters and make sure nothing interferes with its function. Assisting the autopilot in a task is frowned upon, as this occasionally leads the system misinterpreting a pilot's actions as rough conditions affecting the plane, leading to a crash in some cases. It is the pilot's duty to verify what forms of autopilot are on, and make sure the flight director is given the right parameters for the autopilot to fulfill its tasks. Doing so correctly allows for a series of benefits such as reduced workload on the

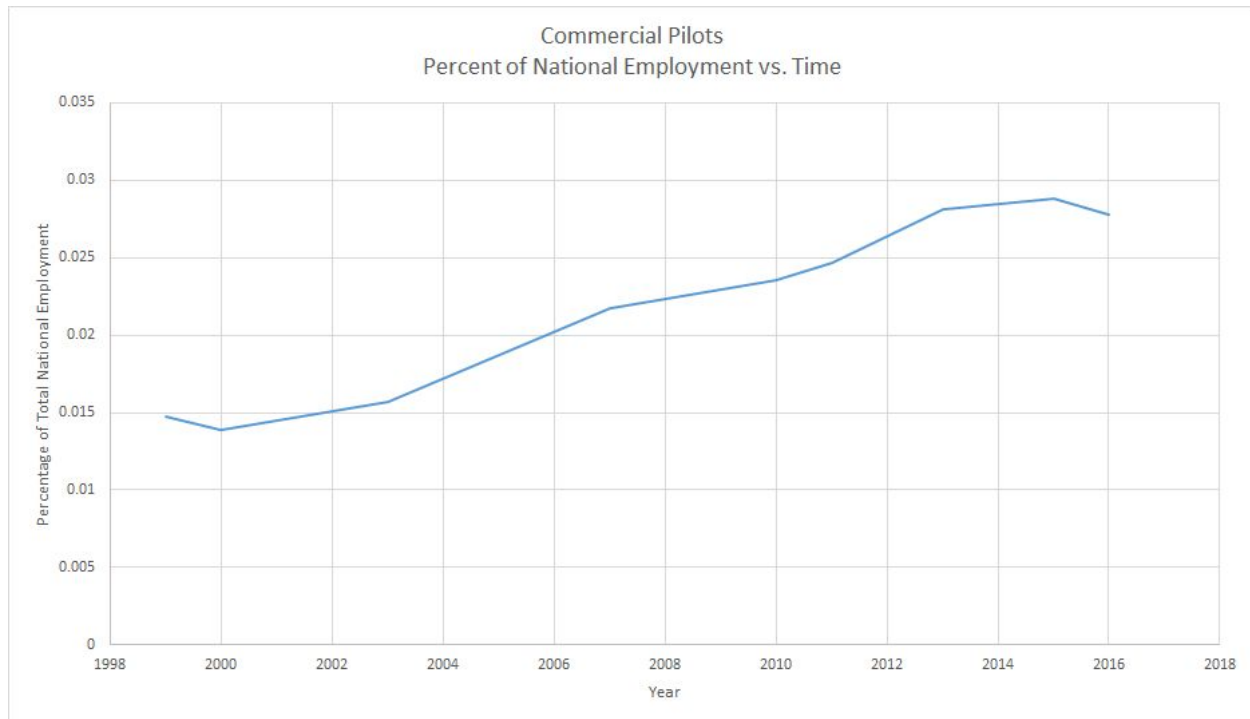
pilot, directing the systems to control the constant and tedious manipulation of aircraft controls. This allows a pilot to focus on reviewing charts, updating weather information, altering routes, or dealing with an emergency situation as examples. These benefits are worthwhile and may be capitalized upon best in an environment autopilot will excel in. There have always been limitations to this technology's capability, such as a minimum altitudes in which it is safe to operate, severe flight conditions, and the potential chance of malfunction for any multitude of reasons. There are benefits and disadvantages to autopilot and the flight director systems. Despite this, they will always be best utilized by a pilot that can give correct programming, recognize its weaknesses, and know when autopilot has exceeded its capabilities, being shut off to allow for manual control (Federal Aviation Administration, 2017).

What was imperative for us to recognize in autopilot's history was that the first successful version of these systems is nearly as old as the first successful plane flight itself (Howard, 1973). Aviation pilots since their inception have always had some form of automation, at the least within the most sophisticated planes of their respective times. Nonetheless, pilots are still controlling aircraft in some capacity on every flight, especially in moments during which autopilot cannot safely operate. Whether it be due to inclement weather, malfunctions, or inaccurate data, there have always been flaws in aircraft autonomy that create the need for a pilot on an aircraft. Since autonomous vehicles not only have to keep the vehicle stable and on correct routes, but also be aware of animals, other vehicles, weather, and more, it is safe to conclude that some semblance of human operation will need to be maintained in self-driving trucks.

Pilots have maintained a need to exist within the airline industry because of the situations autopilot may not account for or be capable of handling properly. Disregarding

this concept only increases the chance of a crash, fatalities, and/or damage to a vehicle. The same could be said of autonomy on trucks. The inability of an autonomous system to be situationally aware of everything at all times as well as being capable of avoiding negative situations prevents truck drivers from being completely phased out of the industry. Nonetheless, pilots go through extensive training to learn about these new systems, while trucking remains as a comparatively entry level job that may reach advancements similar to those of airline pilots. A skill gap may propagate where truck drivers may not be prepared to drive trucks which manage themselves in fleets, or process information and navigation differently than the traditional driver would. Retraining may be an extensive process that can prevent some truckers from breaking into a new form of the same industry, while more educated, new drivers potentially replace them. Either way, it is clear that the decline of licensed truckers and the increasing demand for them will leave space for the job for many years to come, drastically altering how the profession is done as autonomous vehicles progress.

We collected data on airline employment, using years of data collected by the Bureau of Labor Statistics in their Current Population Survey. The data was analyzed in the same manner as those employed in trucking; the number of persons employed as commercial pilots was compared to the number of persons employed nationwide, resulting in a percentage of national employment in the industry, and helping to control for inconsistencies in these surveys from year to year. Figure 4.3.1a, above, shows the results of this data comparison.



*Figure 4.3.1a— Airline employment as a percentage of national employment  
(Bureau of Labor Statistics, n.d.)*

### 4.3.2 Autonomy in Farming Vehicles

Although it gets less media attention, the farming industry is a bit ahead of the automobile industry, in terms of implementing autonomous technology. “For years, John Deere has been selling tractors that practically drive themselves” (Peterson, 2015). Automated milking systems have been in use since the 1990s (Mulligan, 2015). “In 2013, the Japanese developed a robot which uses digital cameras to calculate the ripeness of a strawberry before snipping it from the vine” (Mulligan, 2015). In Boston, a company called Harvest Automation is using robots which distribute and collect container-grown plants in greenhouses (Mulligan, 2015).

The prevalence of automation in farming is in part due to the lack of federal regulations governing the use of tractors, compared to cars, and the fact that collisions with

pedestrians and other vehicles are less of a concern. Andrea Peterson of *The Washington Post* writes:

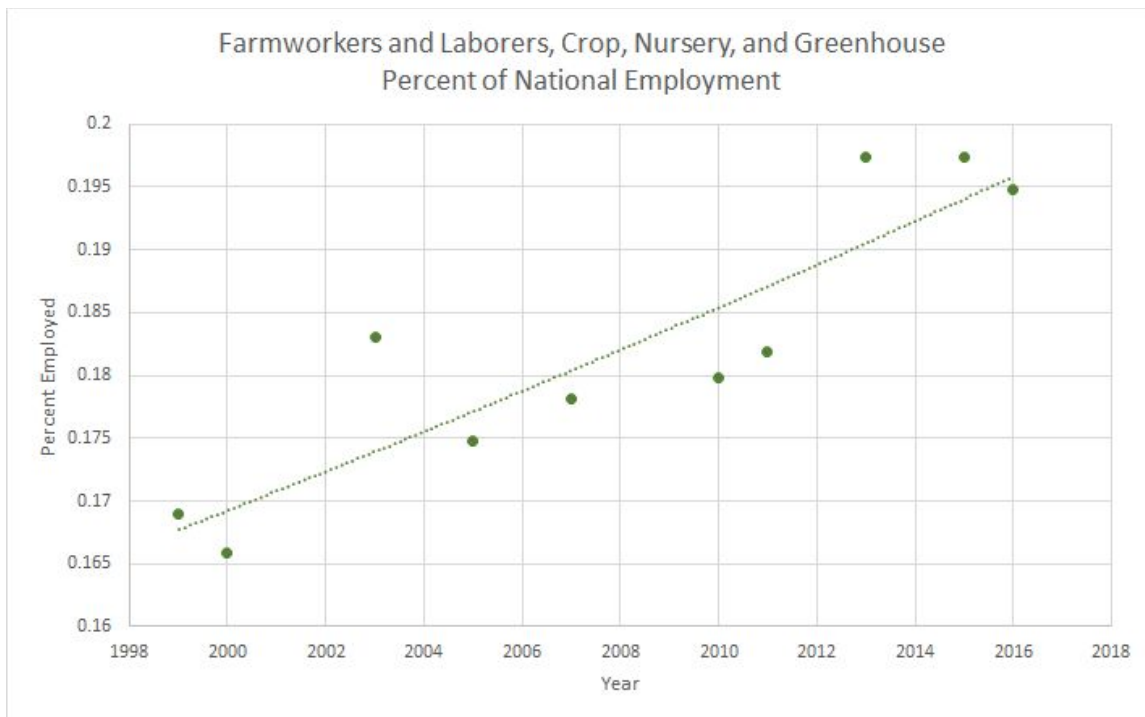
*There are no federal rules specifically addressing self-driving tech for tractors, largely because farm equipment is designed for use in fields where it doesn't pose the same level of risk to other vehicles or people as a self-driving vehicle on a public road. The closest thing to national regulations are safety standards set by the Occupational Safety and Health Administration, but the agency does not have any rules directly aimed at self-driving technology* (Peterson, 2015).

Self-driving technology in agriculture has largely been successful, and could provide guidance for the implementation of self-driving technology in cars and trucks (Peterson, 2015).

Like the trucking industry, the farming industry is facing a major job shortage. In the state of California, labor forces are behind by a sizable margin, despite farms offering competitive, and rising wages (Kitroeff & Mahan, 2017). The *Los Angeles Times* cites new limits to immigrant workers as the culprit for California's job shortages, claiming that Americans simply don't want to do this work (Kitroeff & Mahan, 2017).

We pulled data from the Bureau of Labor Statistics Occupational Employment Statistics reports, over the past twenty years. We looked at two specific employment categories: Farmworkers and Laborers, Crop Nursery and Greenhouse and Agricultural Equipment Operators. The data was analyzed in the same manner as those employed in trucking; the number of persons employed as commercial pilots was compared to the number of persons employed nationwide, resulting in a percentage of national employment in the industry, and helping to control for inconsistencies in these surveys from year to year. Farmworker and Laborer employment was somewhat variable, but demonstrated a

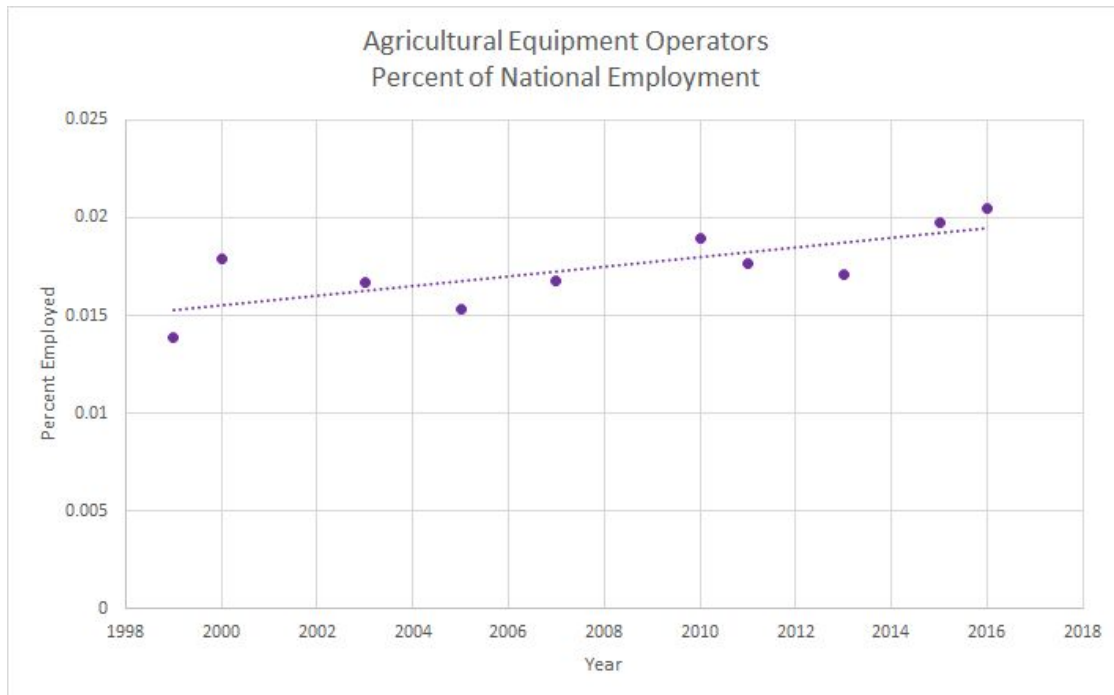
positive slope overall in the past two decades. Employment has been in decline since 2013, however. Figure 4.3.2a, below, is a plot of this data.



*Figure 4.3.2a— Employment of agricultural equipment operators as a percent of national employment*

Agricultural Equipment Operators are the workers we expected to be most affected by the influx of autonomous vehicles into farming. This data analysis showed a positive overall slope for the equipment operators as well, and unlike farm laborers, employment appears to be distinctly increasing since 2013. Figure 4.3.2b, below, is a plot of this data.





*Figure 4.3.2b— Employment of agricultural equipment operators  
as a percent of national employment*

## **5 Discussion and Analysis of Results**

### **5.1 The Threat of Job Loss Due to Autonomous Trucks**

#### **5.1.1 Possibility of Trucker Layoffs is Legitimate**

One of the primary oppositions to autonomy in the trucking industry comes from the truck drivers themselves. Ken Hall, the General Secretary Treasurer of the International Brotherhood of Teamsters spoke to the Senate Committee on Commerce Science and Transportation regarding this issue in September of 2017. The International Brotherhood of Teamsters is a union of 1.4 million members, 600,000 of whom drive a truck for a living (Hall, 2017). Mr. Hall urged lawmakers to protect the employment status of his members in this address, highlighting “the potential impact on the livelihoods and wages of millions of [citizens]” (Hall, 2017).

Computerization of the trucking industry isn’t an idle threat. Studies have shown that jobs requiring a relatively low level of creativity and social-intelligence are those most subject to computerization, a category to which truck driving would fall (Frey & Osborne, 2017). A 2017 model from Frey & Osborne predicts that most workers in the transportation and logistics occupations are at risk for technological replacement (Frey & Osborne, 2017).

The US Department of Commerce Economics and Statistics Administration’s reports have echoed these concerns. This study found that professional motor vehicle operators were at high risk for replacement by computerization (Beede et al., 2017). This study also stated that motor vehicle operators would struggle to find new employment upon being replaced by automation. Only 7.6 percent of all motor vehicle operators have a bachelor’s degree or higher, and 45.6 percent had only a high school diploma, which is nearly twice the national average for all employed individuals, at 24.7 percent (Beede et al., 2017).

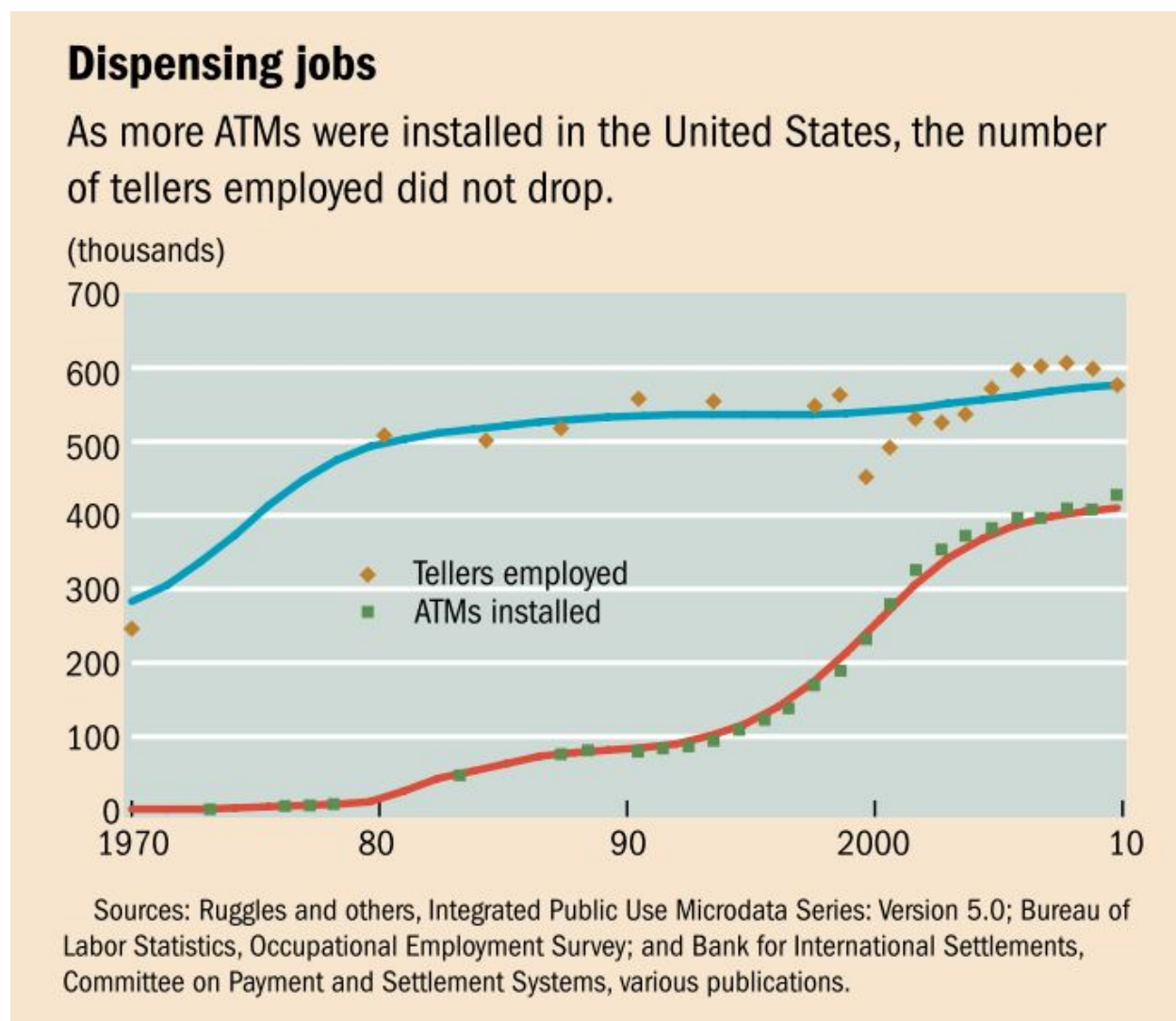
There certainly appear to be merits of limiting the human component of truck driving. Human error is a factor in 87-percent of large truck crashes, and in 94-percent of all vehicle crashes (Spear, 2017). Because the commercial driver spends so much time behind the wheel of their vehicle, they are at risk for errors, as “the sustained mental workload associated with long-term tasks may cause performance to deteriorate” (Bedinger et al., 2015). A 2010 study “found that (relative to private vehicle drivers) commercial vehicle drivers may exhibit stronger stress reactions to traffic conditions and commit more risky driving behaviours” (Bedinger et al., 2015).

### **5.1.2 Hope for Sustained Trucker Employment**

However, the influx of technology into the workplace may not mean that jobs are eliminated. In his 2015 article, James Bessen argues this point. He claims that, “despite fears of widespread technological unemployment... the data show technology today largely displacing workers to new jobs, not replacing them entirely” (Bessen, 2015).

Bessen cites the invention and widespread adoption of automated teller machines (ATMs) as an example circumstance in which technology does not result in joblessness. ATMs successfully replace nearly all of the job functions of a human teller, and it would seem logical that their installation would result in banks cutting back their human employment. ATMs were first installed in the 1970s, and beginning in the mid-1990s, banks rapidly increased their use of the devices (Bessen, 2015). There was no drop in employment of bank tellers as a result (Bessen, 2015). Figure 5.1.2a, below, displays the correlation between the number of ATMs installed and the number of human tellers employed. The number of bank tellers per branch were reduced, but banks chose to open more branches in the wake of ATM adoption—in part due to reduced federal regulations at the time—protecting the number of human tellers employed (Bessen, 2015). “While ATMs

automated some tasks, the remaining tasks that were not automated became more valuable” (Bessen, 2015, p. 17). Customers still had needs that could not be handled by machine, especially with small business customers (Bessen, 2015). These human tellers remained a necessary part of the industry because of the interpersonal-relationships they formed and maintained.



*Figure 5.1.2— Comparing the number of ATMs installed in the United States to the number of persons employed as bank tellers. (Bessen, 2015)*

What happened with ATMs is not an isolated example, and it’s not a new trend either. During the Industrial Revolution of the 19th century, “automation did not create

massive technological unemployment” (Bessen, 2015, p. 17). Power looms automated 98 percent of the the labor needed to weave a yard of cloth, yet the number of factory weaving jobs actually increased over this period (Bessen, 2015). “Less labor cost per yard meant a lower price in competitive markets; a lower price meant sharply increased demand for cloth; and greater demand for cloth increased the demand for weavers despite the drop in labor needed per yard” (Bessen, 2015).

New technology may also increase the demand for workers with new skills, as technological advancements alter the landscape of an industry (Bessen, 2015). Additionally, the increased efficiency and productivity brought about by machines can open up opportunities for increased production and revenues, meaning that human workers are not laid off, even when their role in the production process has been reduced. This is certainly not true across all industries, but these examples demonstrate that technological advancement and job loss are far from a guaranteed pair.

Within the trucking industry, there appears to be a remaining need for human involvement. Hall writes “I have yet to hear a serious discussion about how we will make sure an 80,000 pound automated truck will be able to maneuver around a warehouse or drop yard and not injure the countless workers also occupying that same space” (Hall, 2017). Mr. Spear echoes this sentiment. “While there may be applications where an automated system can take over the driving task, this is unlikely to replace commercial vehicle drivers altogether, just as in the airline industry pilots are still in the cockpit and responsible for the safe operation of their vehicle” (Spear, 2017).

Truckers in synergy with autonomy possess a high chance of being the optimal choice for future operation of a freight vehicle. Self-driving technology would behave as an assistant in complex situations, becoming fully autonomous in environments with less

factors to take into account. The driver would be less fatigued and stressed, minimizing the risk of a driver controlled accident in a situation AVs could be overwhelmed in. Moreover, self-driving technology could take the wheel during mundane, tedious, and simplistic driving to allow a driver to complete other productive tasks. Both the human and computer operators of the truck would utilize their driving prowess in conditions optimal to them in particular, achieving a level of performance and success together that could not be achieved independently. Automation has to this day, been unable to completely replace the job of an aviation pilot over nearly a century of improvements. While we may not expect a similar length of time for truck drivers in a world more technology focused than ever, complete automation won't be immediate. Drivers will remain a need of the trucking industry due to the shortfalls of AVs in general.

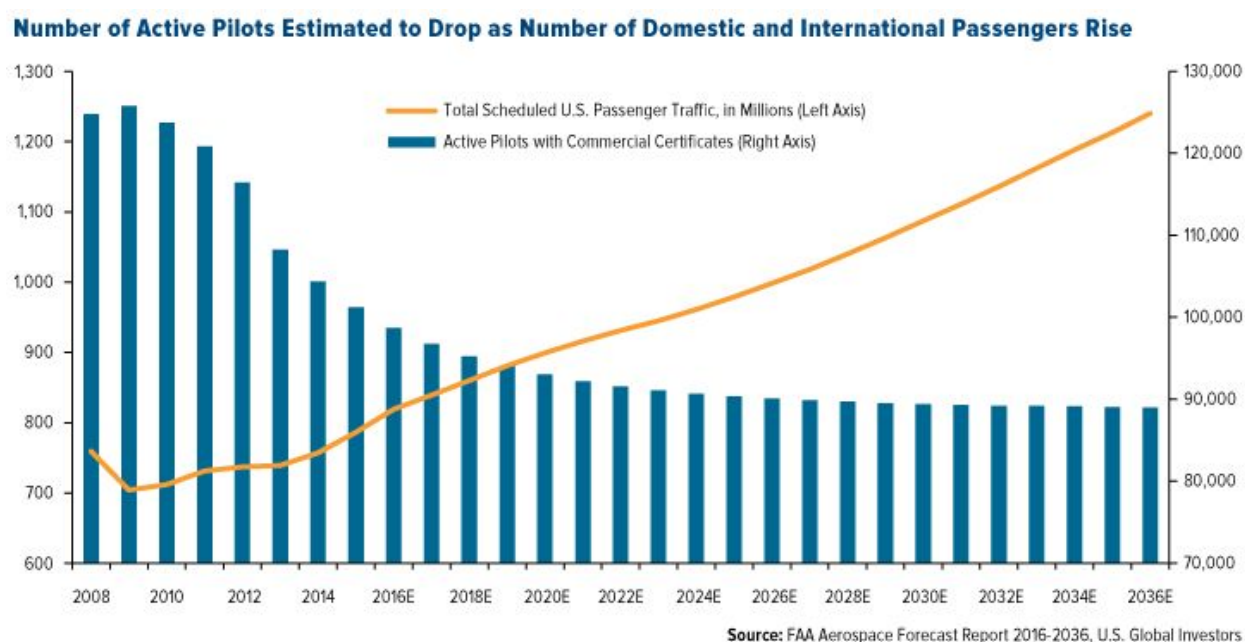
Even in a highly automated environment, an automated vehicle cannot replace many of the tasks required of a commercial driver (Short & Murray, 2016). Truck drivers must represent their trucking company during interactions with shippers and clients, specifically interacting with the shipper regarding specifications of delivery (Short & Murray, 2016). Drivers are responsible for maintenance and inspection of their vehicles and adherence to regulations (Short & Murray, 2016). They plan routes and react to complications due to weather and traffic conditions (Short & Murray, 2016). Truck drivers manually load and unload freight, organize cargo, manage inventory and ensure that cargo is loaded securely (Short & Murray, 2016).

Additionally, there is currently a major shortage of truck drivers within the freight industry. A 2017 report from the American Trucking Associations, listed a shortage in truck drivers of 36,500, and predicts that, based on the current trajectory, the driver shortage will climb above 174,000 jobs by the year 2026 (Costello). Additionally, truck drivers may leave

their jobs for other reasons, whether it be to pursue other opportunities, or are dismissed from their positions due to poor performance or other incident (Costello, 2017).

When looking at other industries that have adopted autonomy before commercial motor vehicles, we see a general trend that supports the theory that truckers will not lose their jobs. Neither the farming nor airline industry have seen a loss in employment of the jobs directly replaced by the autonomous system, as demonstrated by our data analysis in the previous section of this report.

There are quite a few parallels between airline pilots and truckers, specifically. Both positions require a high degree of uninterrupted focus, navigational skill, and knowledge of one's vehicle. Yet an important trait when evaluating the future of trucking employment, is that both truck drivers and pilots experiencing job shortages, as their respective industries are on the rise. Figure 4.3.1a, below, shows this dichotomy for airlines.



*Figure 4.3.1a—Pilot shortage in the airline industry, by year (“Pilot Shortage”, 2017)*

The trucking industry is expected to grow as well (Rivera, 2017a; Rivera, 2017b). Increased utilization of shipping for consumers requires more truckers to meet this need, just as the increase of globalization drives the requirement for more pilots. Based on these similar demands and shortages, it becomes evident that autonomy will help in supplementing the shortage of drivers, rather than replacing the drivers themselves.

The American Transportation Research Institute—the not-for-profit research branch of the trucking industry (Spear, 2017)—hypothesizes that the truck driving career might become more appealing as autonomous vehicles are adopted (Short & Murray, 2016). Their 2016 report writes:

*Alternatively, truck driving as a career may become more attractive as L3 and L4 trucks are commercially available. L3 automation may relieve some of the stress and monotony of driving long hours, and L4 could allow drivers to work on tasks such as logistics while the vehicle is moving. Additionally, the ability to rest while driving in the L4 environment could enable drivers to be at home more often rather than parked at distant locations, and to use equipment and their own labor more productively. Any gains in productivity could likewise decrease the number of trucks and drivers needed to move the nation's freight, which could act to mitigate the driver shortage problem (Short & Murray, 2016).*

This report claims that this new appeal could be especially beneficial in recruiting younger drivers, a severely underrepresented population among truckers (Short & Murray, 2016). The number of truck drivers between the ages of 25 and 34 has decreased by nearly 50 percent in the past 20 years (Short & Murray, 2016). As Spear writes, “highly automated trucks will likely draw new, younger drivers into the trucking industry by better meeting the job expectations of millennial workers” (Spear, 2017).



David H. Autor, a celebrated economist for the Massachusetts Institute of Technology (MIT) corroborates these statements with his 2015 article published in the *Journal of Economic Perspectives*. He writes that technology and automation simply do not result in unemployment. Job descriptions may change, there may be some displacement from one industry to another, but as technology has improved by leaps and bounds over the past centuries, there has been no resultant unemployment (Autor, 2015). He writes:

*the past two centuries of automation and technological progress have not made human labor obsolete: the employment-to-population ratio rose during the 20th century even as women moved from home to market; and although the unemployment rate fluctuates cyclically, there is no apparent long-run increase* (Autor, 2015, p. 4).

Autor also explains that automaton is complementary to labor, because it raises outputs in ways that lead to higher demand for labor and interacts with adjustments in labor supply (Autor, 2015). This parallels the results of ATM and power-loom implementation.

Truckers are limited to only 11 hours of driving each day, and federal regulations are getting better at enforcing this rule (Riviera, 2017b). Automation can allow for longer daily drive-times, since the human in the cockpit doesn't have to be focused the entirety of the time, and since safety concerns are not as great of a threat. Also, many experts expect to see podding of autonomous trucks, where a human driver will operate a lead truck, and some number of other trucks will follow it (Beede et al., 2017; Clements & Kockelman, 2017). These increases will help the trucking industry meet the growing shipping demands of our instant-gratification, rapid-delivery generation, and the human drivers who do not leave the industry in retirement will likely retain a role, even if the number of humans per truck decreases.

Yes, the industry is changing, and the role of the human driver may change as well. But at this time, given what has happened in similar industries, the major shortage of truck drivers, and general economic trends in the past 200 years, we believe there is no cause for concern regarding trucker unemployment, at this time.

## **5.2 The Role of the Federal Government**

Because this concerns an industry that is so dependent on interstate travel, it is vital that we establish consistent regulations for commercial autonomous trucks nationwide. Chris Spear, President and CEO of the American Trucking Associations, Incorporated, writes:

*the trucking industry relies on an interstate highway system that facilitates the free flow of goods between the states. As automated truck technology is developed, tested, and commercialized, it is critical that federal, state and local laws do not create disparities that limit commerce and obstruct the successful adoption of these potentially safety- and productivity-boosting technologies. The regulation of performance and technical specifications of automated and connected truck technology should be solely the responsibility of the federal government. States should maintain their existing responsibilities that do not interfere with the flow of interstate commerce (Spear, 2017).*

Conflicting requirements between federal and state agencies will result in an obstruction of progress in the industry (Spear, 2017). One of the famous failures of the Articles of Confederation was its inability to regulate trade, due to the variety of regulations from one state to another (Brackemyre). Without national regulations, “innovation will be slowed as companies divert resources to addressing a patchwork of state policies” (Spear, 2017).

The federal government, has a pivotal role in this process. It is important that they decide on some national standards, so that autonomous trucking can continue to grow. Ultimately, safety concerns are paramount, but a failure to act on this issue will result in a stagnant trucking industry.

## 6 Conclusion and Future Work

Autonomy is a technology progressing in advancement at a rapid rate, yet this fact doesn't act as proof that truck driving as a profession will face a decline. Truckers are in demand now more than ever, with shipping on the rise from an increasingly productive and globalized economy. Additionally, the observations we have made on aviation and other industries where autonomy has threatened human employment can offer insight in modeling what we expect to see as autonomy is implemented in trucking. Pilots, as well as the other industries evaluated faced similar threats of job replacement due to autonomy, and the employment of humans in these industries has continued.

### 6.1 Summary of Findings and Analysis

Our findings and analysis chapter focused on two main topics, the potential threat of job loss for truck drivers due to autonomous trucks and the role the federal government needs to play as this technology becomes more advance and widely used.

A primary opposition to the implementation of autonomous trucks comes from the truck drivers themselves. Ken Hall, the General Secretary Treasurer of the International Brotherhood of Teamsters spoke to the Senate Committee on Commerce Science and Transportation regarding this issue in September of 2017. The International Brotherhood of Teamsters is a union of 1.4 million members, 600,000 of whom drive a truck for a living (Hall, 2017). Mr. Hall urged lawmakers to protect the employment status of his members in this address, highlighting “the potential impact on the livelihoods and wages of millions of [citizens]” (Hall, 2017).

Not all believe that there is much to fear from autonomous trucks however, James Bessen argues that, “despite fears of widespread technological unemployment... the data show technology today largely displacing workers to new jobs, not replacing them entirely”

(Bessen, 2015). He goes on to say, “just because computers can perform some job tasks does not mean that jobs will be eliminated” (Bessen, 2015). He uses the example of ATMs and bank tellers to show how automation does not mean the end of a job necessarily. New technology may even increase the demand for workers with new skills as the technology becomes more widely used (Bessen, 2015).

Even with the current autonomous technology there still will be a need for a driver to be present. Hall writes “I have yet to hear a serious discussion about how we will make sure an 80,000 pound automated truck will be able to maneuver around a warehouse or drop yard and not injure the countless workers also occupying that same space” (Hall, 2017). This sentiment can be related back to both the correlation between ATM’s/bank tellers as well as the correlation between airline pilots and autopilot. Mr. Spear remarks that “this is unlikely to replace commercial vehicle drivers altogether, just as in the airline industry pilots are still in the cockpit and responsible for the safe operation of their vehicle” (Spear, 2017). Therefore until autonomous driving technology becomes more advanced and refined we can conclude that drivers will still occupy autonomous trucks in the near future.

Having truckers work in sync with the a trucks automation could also provide benefits. This means that the trucks automation could assist the driver in complex situations, take over driving on long highways, allowing the driver to perform other productive tasks while the truck is moving as well as reduce the amount of stress or fatigue a driver might experience in a regular semi truck. Furthermore, even with automation the tasks required of a commercial driver during deliveries will remain. Truck drivers must represent their trucking company during interactions with shippers and clients, specifically interacting with the shipper regarding specifications of delivery (Short & Murray, 2016). On

top of this drivers are also responsible for the maintenance, inspection, and adherence to regulations (Short & Murray, 2016).

There is also currently a shortage of truck drivers within the freight industry. A report from the American Trucking Associations showed a shortage of 47,500 in 2015 and predicts that if the trend were to continue the shortage could climb to over 150,000 jobs by 2024 (Costello & Suarez, 2015). Furthermore this shortage of truck drivers may also be due to truck drivers deciding to leave the profession for other reasons either to pursue other opportunities or because they were let go for poor performance. (Costello & Suarez, 2015). In order to counteract this shortage the American Transportation Research Institute hypothesizes that the truck driving career might become more appealing as autonomous vehicles are adopted (Short & Murray, 2016). The report claims that as L3 and L4 autonomous trucks become commercially available the new appeal could be helpful in recruiting younger drivers which as stated before is an extremely underrepresented portion of the truck driver population (Short & Murray, 2016).

As stated before this shortage of workers with at the same time an increase in demand for shipping services can be found not only in the trucking industry but also with airline pilots. Automation could possibly be the answer to this problem, helping to supplement these shortages, while the eased workload and reduced stress of the profession will help possibly bring in new workers.

Finally we found that the federal government needs to play a central role in shaping policy to allow self driving trucks to become commercially available. “The trucking industry relies on an interstate highway system that facilitates the free flow of goods between the states. As automated truck technology is developed, tested, and commercialized, it is critical that federal, state and local laws do not create disparities that limit commerce and obstruct

the successful adoption of these potentially safety- and productivity-boosting technologies” (Spear, 2017). Therefore it is paramount that the federal government have sole responsibility over shaping policy for automated vehicles so as not to create any limitations or hindrances to innovation and commerce.

## **6.2 Project Success with Respect to Research Goals**

Ultimately, we can not prove our thesis with absolute certainty that truck driving will not be as severely impacted by autonomy as is commonly thought, as too many unknown variables exist that cannot be factored in, at this point and time. Business impact could not be properly measured due to a lack of available data on the ways in which road freight businesses will gain or lose revenue due to AVs. This prevented a proper assessment on consumer impact through how these revenue changes will affect product prices. Government involvement with self-driving trucks although vital to the advancement of the technology is not widespread throughout the states as of this report, which made establishing footholds for our thesis difficult. Yet the most successful data we have found throughout the process of creating this report were those of the current landscape of the trucking industry, as well as the parallels discovered in similar industries. Automation threatens various professions, but the success of the report came in the fact that many of these parallel professions have implemented autonomy in some fashion for decades. This gave us an understanding of how truckers can adjust, adapt, and thrive alongside AV technology, instead of continuing an unemployment decline.

## **6.3 Project Difficulties & Sources of Error**

An initial goal of this report was to create a well supported timeline on when we can expect autonomous trucks to become widespread, as well as predict how and when truck driving as a job will be affected. As research continued, we became increasingly aware of

how the data that would support this goal in particular was either inconsistent over a long period of time, was unavailable, or non-existent. The Bureau of Labor Statistics while helpful in our endeavors, has altered how it categorizes data collected over the years. While the most recent trucking employment data covered the industries we required, data from the 80s and mid 90s was evaluated every three years instead of annually, not including individual industry reports consistently within those three year periods. This made it difficult for a timeline to be developed for trucking over the decades, as old data was evaluated in different ways. Additionally, no reliable timeline was discovered from legitimate sources, whether it be through a federal department, company, or state. Revenue information was also a difficult search due to the various companies within the trucking industry maintaining privacy on revenue. For these key reasons, we were unable to construct a timeline for autonomous trucking and its effects on the trucking industry. Nonetheless, to the best of our ability we were able to find trends of employment and technological advancements with a high likelihood of occurring in the near future, which assisted in solidifying the basis for our thesis.

## **6.4 Next Steps**

It is important with continued research to revisit certain topics addressed in this report, as AVs as a whole are still in developmental stages. Additionally, legislation for autonomous trucks while in discussion in the U.S. have not been established, and possess the potential to alter our predicted outcomes of the trucking industry responding to autonomy. For example, autonomous trucks in platoons or fleets resembling a multi-car train can save fuel up to 8% for the lead vehicle, and up to 14% for the trucks following close behind (Roland Berger, 2015). Additionally, the closely packed trucks could increase road capacity by 500% resulting in infrastructure savings of potentially \$7.5 billion annually



(Clements & Kockelman, 2017). While promising from an efficiency standpoint, we do not yet know if it will be legally mandatory for a human driver to be present in all the trucks in a platoon, or just the lead truck. This unfortunately leads to an uncertainty about future trucker employment, especially since platooning is a concept for AVs being heavily explored as a fuel saving strategy that could become commonplace amongst these vehicles. Many unknown variables such as this cannot be factored in with great confidence as regulations and laws have not been put in place to provide a solid foundation. As autonomy becomes more and more widespread, government will play a more pivotal role, and a more accurate depiction of future truck driver employment can be drawn.

## 7 Works Cited

- Bedinger, M., Walker, G. H., Piecyk, M., & Greening, P. (2015). 21st century trucking: A trajectory for ergonomics and road freight. *Applied Ergonomics*, 53(B), 343–356.  
<https://doi.org/10.1016/j.apergo.2015.06.022>
- Beede, D., Powers, R., & Ingram, C. (2017). Executive Summary The Employment Impact of Autonomous Vehicles. US Department of Commerce Economics and Statistics Administration, 17(5), 1–33. Retrieved from  
[http://www.esa.doc.gov/sites/default/files/Employment\\_Impact\\_Autonomous\\_Vehicles\\_0.pdf](http://www.esa.doc.gov/sites/default/files/Employment_Impact_Autonomous_Vehicles_0.pdf)
- Bessen, J. (2015). Toil and technology: Innovative technology is displacing workers to new jobs rather than replacing them entirely. *Finance and Development*.
- Blincoe, L., Miller, T. R., & Zaloshnja, E. (2015). The Economic and Societal Impact Of Motor Vehicle Crashes, 2010 (Revised). National Highway Traffic Safety Administration. US Department of Transportation.
- Brackemyre, T. (n.d.). America's First Failure at Government: The Articles of Confederation. Retrieved December 16, 2017, from  
<http://ushistoryscene.com/article/articles-of-confederation/>
- Bureau of Labor Statistics. (n.d.). Current Population Survey. US Department of Labor. Retrieved from <https://www.bls.gov/cps/tables.htm>
- Bureau of Labor Statistics. (n.d.). Occupational Employment Statistics. US Department of Labor. Retrieved from <https://www.bls.gov/oes/tables.htm>
- Bureau of Labor Statistics (U.S. Department of Labor). (2015). Heavy and Tractor-trailer Truck Drivers. Retrieved November 6, 2017, from  
<https://www.bls.gov/oes/current/oes533032.htm#st>

- Cameron, O. (2017). An Introduction to LIDAR: The Key Self-Driving Car Sensor. Retrieved March 12, 2018, from <https://news.voyage.auto/an-introduction-to-lidar-the-key-self-driving-car-sensor-a7e405590cff>
- Clements, L. M., & Kockelman, K. M. (2017). Economic Effects of Automated Vehicles. Transportation Research Record, (2602). Retrieved from [http://www.caee.utexas.edu/prof/kockelman/public\\_html/TRB17EconomicEffectsofAVs.pdf](http://www.caee.utexas.edu/prof/kockelman/public_html/TRB17EconomicEffectsofAVs.pdf)
- Clevenger, S. (2018). Embark Self-Driving Truck Completes Coast-to-Coast Test Run. Retrieved March 4, 2018, from <http://www.ttnews.com/articles/embark-self-driving-truck-completes-coast-coast-test-run>
- Costello, B., & Suarez, R. (2015, October). Truck Driver Shortage Analysis 2015. American Trucking Associations. Retrieved from [http://www.trucking.org/ATA\\_Docs/News and Information/Reports Trends and Statistics/10 6 15 ATAs Driver Shortage Report 2015.pdf](http://www.trucking.org/ATA_Docs/News_and_Information/Reports_Trends_and_Statistics/10_6_15_ATAs_Driver_Shortage_Report_2015.pdf)
- Deagon, B. (2017, February 3). Robotrucks Hit The Road In the Name Of Safety, Efficiency And Profit. Investor's Business Daily, pp. 1–5.
- Etherington, D. (2017). U.S. House of Representatives passes new bipartisan self-driving car bill. Retrieved December 16, 2017, from <https://techcrunch.com/2017/09/06/u-s-house-of-representatives-passes-new-bipartisan-self-driving-car-bill/>
- Federal Aviation Administration. (2017). Advanced Avionics Handbook Chapter 4: Automated Flight Control. Retrieved from

[https://www.faa.gov/regulations\\_policies/handbooks\\_manuals/aviation/advanced\\_aviationics\\_handbook/media/aah\\_ch04.pdf](https://www.faa.gov/regulations_policies/handbooks_manuals/aviation/advanced_aviationics_handbook/media/aah_ch04.pdf)

Federal Aviation Administration. (2012). Fair Treatment of Experienced Pilots Act (The Age 65 Law) Information, Questions and Answers. Retrieved from [https://www.faa.gov/other\\_visit/aviation\\_industry/airline\\_operators/airline\\_safety/info/all\\_infos/media/age65\\_qa.pdf](https://www.faa.gov/other_visit/aviation_industry/airline_operators/airline_safety/info/all_infos/media/age65_qa.pdf)

Fichter, K. (2017, May 18). IEEE VTS Connected & Autonomous Vehicles Summer School. Worcester, MA: Worcester Polytechnic Institute.

(2015, May 5). Freightliner Inspiration Truck Receives Autonomous Vehicle Licensing from Nevada DMV. India Automobile News.

Frey, C. B., & Osborne, M. A. (2017). The future of employment: How susceptible are jobs to computerisation? *Technological Forecasting & Social Change*, 114, 254–280. <https://doi.org/10.1016/j.techfore.2016.08.019>

Hall, K. (2017, September 13). Testimony for Senate Commerce Hearing on Transportation Innovation: Automated Trucks and Our Nation's Highways. Senate Committee on Commerce, Science, and Transportation.

Havemann, J. (2009). The Financial Crisis of 2008. In *Encyclopædia Britannica*. Encyclopædia Britannica, Inc. Retrieved from <https://www.britannica.com/topic/Financial-Crisis-of-2008-The-1484264>

Hawkins, A. (2017). These nine states will serve as testing grounds for self-driving cars. Retrieved December 16, 2017, from <https://www.theverge.com/2017/1/23/14357564/dot-self-driving-car-testing-sites-nine-states>

Heutger, M., & Kückelhaus, M. (2014). SELF-DRIVING VEHICLES IN LOGISTICS.

Retrieved from

[http://www.dhl.com/content/dam/downloads/g0/about\\_us/logistics\\_insights/dhl\\_self\\_driving\\_vehicles.pdf](http://www.dhl.com/content/dam/downloads/g0/about_us/logistics_insights/dhl_self_driving_vehicles.pdf)

Holley, P. (2018, March 9). Waymo's self-driving trucks will arrive on Georgia roads next week. Washington Post, p. 1. Retrieved from

[https://www.washingtonpost.com/news/innovations/wp/2018/03/09/waymos-self-driving-trucks-will-arrive-on-georgia-roads-next-week/?utm\\_term=.4a706a13055f](https://www.washingtonpost.com/news/innovations/wp/2018/03/09/waymos-self-driving-trucks-will-arrive-on-georgia-roads-next-week/?utm_term=.4a706a13055f)

Howard, R. W. (1973). AUTOMATIC FLIGHT CONTROLS IN FIXED WING AIRCRAFT: THE FIRST 100 YEARS. *Aeronautical Journal*, 533–562.

Kitroeff, N., & Mahan, G. (2017, March 17). Wages rise on California farms. Americans still don't want the job. Los Angeles Times. Retrieved from

<http://www.latimes.com/projects/la-fi-farms-immigration/>

Mulligan, C. (2015). The Automation of Agriculture, Part I. Retrieved December 6, 2017, from

<https://www.fcc-fac.ca/en/ag-knowledge/ag-economics/the-automation-of-agriculture-part-one.html>

NHTSA. (2017). Automated Driving Systems 2.0: A Vision For Safety. U.S. Department of Transportation.

Padleckas, H. (2011). Conventional 18-Wheeler Truck Diagram. Retrieved from

[https://commons.wikimedia.org/wiki/File:Conventional\\_18-wheeler\\_truck\\_diagram.svg](https://commons.wikimedia.org/wiki/File:Conventional_18-wheeler_truck_diagram.svg)

Peterson, A. (2015, June 22). Google didn't lead the self-driving vehicle revolution. John Deere did. The Washington Post. Retrieved from

- [https://www.washingtonpost.com/news/the-switch/wp/2015/06/22/google-didnt-lead-t  
he-self-driving-vehicle-revolution-john-deere-did/?utm\\_term=.1d551c7a8d94](https://www.washingtonpost.com/news/the-switch/wp/2015/06/22/google-didnt-lead-t<br/>he-self-driving-vehicle-revolution-john-deere-did/?utm_term=.1d551c7a8d94)
- Renner, D. A. (1998). Cross-country Truck Drivers: A Vulnerable Population. *Nursing Outlook*, 46(4), 164–168.
- Rivera, E. (2017). Long-Distance Freight Trucking in the US. IBIS World. Retrieved from <http://clients1.ibisworld.com/reports/us/industry/default.aspx?entid=1150>
- Rivera, E. (2017). Local Freight Trucking in the US. IBIS World. Retrieved from <http://clients1.ibisworld.com/reports/us/industry/keystatistics.aspx?indid=1149>
- Roland Berger Strategy Consultants GmbH. (2015). On the Road Toward the Autonomous Truck: Opportunities for OEMs and Suppliers. Retrieved from [https://www.rolandberger.com/en/Publications/pub\\_autonomous\\_truck.html](https://www.rolandberger.com/en/Publications/pub_autonomous_truck.html)
- Scheck, W. (2017). Lawrence Sperry: Genius on Autopilot | HistoryNet. Retrieved March 12, 2018, from <http://www.historynet.com/lawrence-sperry-autopilot-inventor-and-aviation-innovator.htm>
- Short, J., & Murray, D. (2016, October). Identifying Autonomous Vehicle Technology Impacts on the Trucking Industry. American Transportation Research Institute. Retrieved from <http://atri-online.org/wp-content/uploads/2016/11/ATRI-Autonomous-Vehicle-Impacts-11-2016.pdf>
- Spear, C. (2017, September 13). Testimony for Senate Commerce Hearing on Transportation Innovation: Automated Trucks and Our Nation’s Highways. Senate Committee on Commerce, Science, and Transportation, pp. 1–8.

- Thune, J., & Peters, G. (2017, September 13). Senate Commerce Hearing on Transportation Innovation: Automated Trucks and Our Nation's Highways. Senate Committee on Commerce, Science, and Transportation.
- Torrey, W. F., & Murray, D. (2014). An Analysis of the Operational Costs of Trucking: 2014 Update.
- Torrey, W. F., & Murray, D. (2014). An Analysis of the Operational Costs of Trucking: 2014 Update.
- Truckinginfo. (2017). Volvo Demonstrates Autonomous Truck Technology. Retrieved March 4, 2018, from <http://www.truckinginfo.com/channel/equipment/news/story/2017/11/volvo-demonstrates-autonomous-truck-technology.aspx>
- U.S. Global ETFs. (2017). Pilot Shortage: A Blessing in Disguise? Retrieved March 10, 2018, from <https://www.usglobaletf.com/insights/pilot-shortage-a-blessing-in-disguise/>
- Vehicle Valuation Services, I. (n.d.). Truck/Tractor & Trailer Glossary of Terms. Oakbrook Terrace, IL: Vehicle Valuation Services, Inc. Retrieved from <http://www.vvsi.com/Assets/training-guides/Glossary-of-Terms-4.pdf>
- Wadud, Z. (2017). Fully automated vehicles: A cost of ownership analysis to inform early adoption. Transportation Research Part A: Policy and Practice. <https://doi.org/10.1016/j.tra.2017.05.005>
- Wakabayashi, D. (2018, March 6). Uber's Self-Driving Trucks Hit the Highway, but Not Local Roads. New York Times, p. 1. Retrieved from <https://www.nytimes.com/2018/03/06/technology/uber-self-driving-trucks.html>

Wise, D. (2016). VEHICLE CYBERSECURITY: DOT and Industry Have Efforts Under Way, but DOT Needs to Define Its Role in Responding to a Real-world Attack. United States Government Accountability Office.



## 8 Appendices

### 8.1 Appendix A: Complete Bibliography

- Anderson, J. M., Kalra, N., Stanley, K. D., Sorensen, P., Samaras, C., & Oluwatola, O. A. (2016). *Autonomous Vehicle Technology: A Guide for Policymakers*. Santa Monica, California: RAND Corporation. Retrieved from [https://www.rand.org/content/dam/rand/pubs/research\\_reports/RR400/RR443-2/RAND\\_RR443-2.pdf](https://www.rand.org/content/dam/rand/pubs/research_reports/RR400/RR443-2/RAND_RR443-2.pdf)
- Anderson, J. M., Kalra, N., Stanley, K. D., Sorensen, P., Samaras, C., & Oluwatola, O. A. (2014). The Promise and Perils of Autonomous Vehicle Technology. In *Autonomous Vehicle Technology: A Guide for Policymakers* (pp. 9–40). RAND Corporation. <https://doi.org/10.7249/j.ctt5hhwgz.9>
- Anderson, J. M., Kalra, N., Stanley, K. D., Sorensen, P., Samaras, C., & Oluwatola, O. A. (2014). Standards and Regulations and Their Application to Autonomous Vehicle Technologies. In *Autonomous Vehicle Technology: A Guide for Policymakers* (pp. 97–109). RAND Corporation. <https://doi.org/10.7249/j.ctt5hhwgz.13>
- Arinze, B., Ndubizu, G., & Sylla, C. (2013). *Forecasting the Impact of Self-Driving Vehicles on US Employment in the Road Transportation Industry Using the Technology Diffusion Model*. Northeast Region Decision Sciences Institute (NEDSI).
- ATA. (2017). *American Trucking Association Industry Data*. Retrieved November 15, 2017, from [http://www.trucking.org/News\\_and\\_Information\\_Reports\\_Industry\\_Data.aspx](http://www.trucking.org/News_and_Information_Reports_Industry_Data.aspx)
- AUSTIN, A., BUCKNOR, C., CASHMAN, K., & ROCKEYMOORE, M. (n.d.). *Center for Global Policy Solutions Stick Shift: Autonomous Vehicles, Driving Jobs and the Future of Work*. Retrieved November 6, 2017, from

<http://globalpolicysolutions.org/report/stick-shift-autonomous-vehicles-driving-jobs-and-the-future-of-work/>

Autor, D. (2015). Why Are There Still So Many Jobs? The History and Future of Workplace Automation. *Journal of Economic Perspectives—Volume*, 29(3), 3–30.

<https://doi.org/10.1257/jep.29.3.3>

Bagloee, S. A., Tavana, @bullet Madjid, Asadi, M., & Oliver, T. (2016). Autonomous vehicles: challenges, opportunities, and future implications for transportation policies. *Journal of Modern Transportation*, 24.

<https://doi.org/10.1007/s40534-016-0117-3>

Bansal, P., Kockelman, K. M., & Schoch, E. P. (2017). Forecasting Americans long-term adoption of connected and autonomous vehicle technologies.

<https://doi.org/10.1016/j.tra.2016.10.013>

Bansal, P., Kockelman, K. M., & Singh, A. (2016). Assessing public opinions of and interest in new vehicle technologies: An Austin perspective.

<https://doi.org/10.1016/j.trc.2016.01.019>

Bedinger, M., Walker, G. H., Piecyk, M., & Greening, P. (2015). 21st century trucking: A trajectory for ergonomics and road freight. *Applied Ergonomics*, 53(B), 343–356.

<https://doi.org/10.1016/j.apergo.2015.06.022>

Beede, D., Powers, R., & Ingram, C. (2017). Executive Summary The Employment Impact of Autonomous Vehicles. US Department of Commerce Economics and Statistics Administration, 17(5), 1–33. Retrieved from

[http://www.esa.doc.gov/sites/default/files/Employment\\_Impact\\_Autonomous\\_Vehicles\\_0.pdf](http://www.esa.doc.gov/sites/default/files/Employment_Impact_Autonomous_Vehicles_0.pdf)

- Bergeron, H. P. (1983). GENERAL AVIATION SINGLE PILOT IFR AUTGPILOT STUDY. Langley Research Center. Retrieved from <https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19810010519.pdf>
- Bessen, J. (2015). Toil and technology: Innovative technology is displacing workers to new jobs rather than replacing them entirely. Finance and Development.
- Blincoe, L., Miller, T. R., & Zaloshnja, E. (2015). The Economic and Societal Impact Of Motor Vehicle Crashes, 2010 (Revised). National Highway Traffic Safety Administration. US Department of Transportation.
- Bonnefon, J.-F., Shariff, A., & Rahwan, I. (2015). Autonomous Vehicles Need Experimental Ethics: Are We Ready for Utilitarian Cars?
- Brackemyre, T. (n.d.). America's First Failure at Government: The Articles of Confederation. Retrieved December 16, 2017, from <http://ushistoryscene.com/article/articles-of-confederation/>
- Bureau of Labor. (2016). Occupational Employment Statistics: Heavy and Tractor-Trailer Truck Drivers. Retrieved October 5, 2017, from <https://www.bls.gov/oes/current/oes533032.htm>
- Bureau of Labor Statistics. (n.d.). Current Population Survey. US Department of Labor. Retrieved from <https://www.bls.gov/cps/tables.htm>
- Bureau of Labor Statistics. (n.d.). Occupational Employment Statistics. US Department of Labor. Retrieved from <https://www.bls.gov/oes/tables.htm>
- Bureau of Labor Statistics (U.S. Department of Labor). (2015). Heavy and Tractor-trailer Truck Drivers. Retrieved November 6, 2017, from <https://www.bls.gov/oes/current/oes533032.htm#st>

- Bureau of Transportation Statistics. (n.d.). Table 1-11: Number of U.S. Aircraft, Vehicles, Vessels, and Other Conveyances | Bureau of Transportation Statistics. Retrieved November 6, 2017, from [https://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/national\\_transportation\\_statistics/html/table\\_01\\_11.html](https://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/national_transportation_statistics/html/table_01_11.html)
- C.A.E. (2016). Airline Pilot Demand, 10-year outlook at a glance Pilot age in 2016 New pilots required for growth and replacement. Retrieved from [http://www.cae.com/uploadedFiles/Content/BusinessUnit/Civil\\_Aviation/CAE-Airline-Pilot-Demand-Outlook-Spread.pdf](http://www.cae.com/uploadedFiles/Content/BusinessUnit/Civil_Aviation/CAE-Airline-Pilot-Demand-Outlook-Spread.pdf)
- Cameron, O. (2017). An Introduction to LIDAR: The Key Self-Driving Car Sensor. Retrieved March 12, 2018, from <https://news.voyage.auto/an-introduction-to-lidar-the-key-self-driving-car-sensor-a7e405590cff>
- Carey, B. (n.d.). FAA's Oversight of Pilot Automation Training Questioned. Retrieved December 6, 2017, from <https://www.ainonline.com/aviation-news/air-transport/2016-01-12/faas-oversight-pilot-automation-training-questioned>
- Cassetta, E., Marra, A., Pozzi, C., & Antonelli, P. (2017). Emerging technological trajectories and new mobility solutions. A large-scale investigation on transport-related innovative start-ups and implications for policy. *Transportation Research Part A: Policy and Practice*, 106, 1–11. <https://doi.org/10.1016/j.tra.2017.09.009>
- Cassidy, W. B. (2017). Uber's Big Play for Small Truckers. *Journal of Commerce*.

- Cassidy, W. B. (2017). Uber Freight aims to deliver untapped capacity. *Journal of Commerce*.
- Cassidy, W. B. (2017). SURFACE & DOMESTIC TRANSPORTATION.
- Cassidy, W. B. (2017). Uber Freight aims to deliver untapped capacity. *Journal of Commerce*.
- Chappell, L. (2014, October 13). Nissan commercial fleet to get self-driving tech. *Automotive News*.
- Chialastri, A. (n.d.). Automation in Aviation.
- Clarke, T. (2017, September 13). Testimony for Senate Commerce Hearing on Transportation Innovation: Automated Trucks and Our Nation's Highways. Senate Committee on Commerce, Science, and Transportation.
- Clements, L. M., & Kockelman, K. M. (2017). Economic Effects of Automated Vehicles. *Transportation Research Record*, (2602). Retrieved from [http://www.caee.utexas.edu/prof/kockelman/public\\_html/TRB17EconomicEffectsofAVs.pdf](http://www.caee.utexas.edu/prof/kockelman/public_html/TRB17EconomicEffectsofAVs.pdf)
- Clevenger, S. (2018). Embark Self-Driving Truck Completes Coast-to-Coast Test Run. Retrieved March 4, 2018, from <http://www.ttnews.com/articles/embark-self-driving-truck-completes-coast-coast-test-run>
- Costello, B. (2017). Truck Driver Shortage Analysis 2017. American Trucking Associations. Retrieved from <http://progressive2.acs.playstream.com/truckline/progressive/ATAsDriverShortageReport2017.pdf>
- Costello, B., & Suarez, R. (2015, October). Truck Driver Shortage Analysis 2015. American Trucking Associations. Retrieved from [http://www.trucking.org/ATA\\_Docs/News and](http://www.trucking.org/ATA_Docs/News_and)

Information/Reports Trends and Statistics/10 6 15 ATAs Driver Shortage Report  
2015.pdf

CSX. (2016). CSX in Massachusetts. Retrieved from

<https://www.csx.com/index.cfm/library/files/about-us/state-information/massachusetts/>

CSX. (2016). CSX Company Overview. Retrieved from

<https://www.csx.com/index.cfm/library/files/about-us/state-information/csx-company-overview/>

Daku, S. A., & Stupnisky, R. (2017). The Relationship Between Motivation and Job Preferences in Commercial Aviation Graduates. *International Journal of Aviation International Journal of Aviation, Aeronautics, and Aerospace*, 4(42).

<https://doi.org/10.15394/ijaa.2017.1158>

Daziano, R. A., Sarrias, M., & Leard, B. (2017). Are consumers willing to pay to let cars drive for them? Analyzing response to autonomous vehicles. *Transportation Research Part C: Emerging Technologies*. <https://doi.org/10.1016/j.trc.2017.03.003>

Deagon, B. (2017, February 3). Robotrucks Hit The Road In the Name Of Safety, Efficiency

And Profit. *Investor's Business Daily*, pp. 1–5.

Deloitte. (2016). Global Truck Study 2016 The Truck Industry in Transition. Retrieved from

<https://www2.deloitte.com/content/dam/Deloitte/us/Documents/manufacturing/us-manufacturing-global-truck-study-the-truck-industry-in-transition.pdf>

Dotson, T. (2017). *Intelligently Steering Toward More Communitarian Technological Societies*. In *Technically Together*. MIT Press. Retrieved from

<http://www.jstor.org/stable/pdf/j.ctt1s476z5.13.pdf?refreqid=excelsior%3A9c3b0774b5868fcdf4a40ed7cceabeae>

- Driver, A. (2013). OFC13: Driverless tractors and robots to be the future of farming | News | Farmers Guardian. Retrieved December 5, 2017, from <https://archive.li/WP3S7>
- Driver, T., & Update, S. (2015). American Trucking Associations on Truck driver shortage. Retrieved November 15, 2017, from [http://www.trucking.org/News\\_and\\_Information\\_Reports\\_Driver\\_Shortage.aspx](http://www.trucking.org/News_and_Information_Reports_Driver_Shortage.aspx)
- Etherington, D. (2017). U.S. House of Representatives passes new bipartisan self-driving car bill. Retrieved December 16, 2017, from <https://techcrunch.com/2017/09/06/u-s-house-of-representatives-passes-new-bipartisan-self-driving-car-bill/>
- Fagnant, D. J., & Kockelman, K. (2015). Preparing a nation for autonomous vehicles: Opportunities, barriers and policy recommendations. *Transportation Research Part A: Policy and Practice*, 77, 167–181. <https://doi.org/10.1016/j.tra.2015.04.003>
- Fagnant, D. J., & Kockelman, K. M. (2014). The travel and environmental implications of shared autonomous vehicles, using agent-based model scenarios. *Transportation Research Part C: Emerging Technologies*, 40, 1–13. <https://doi.org/10.1016/j.trc.2013.12.001>
- Federal Aviation Administration. (2016). The Impact of Civil Aviation on the U.S. Economy. Retrieved from [https://www.faa.gov/air\\_traffic/publications/media/2016-economic-impact-report\\_FINAL.pdf](https://www.faa.gov/air_traffic/publications/media/2016-economic-impact-report_FINAL.pdf)
- Federal Aviation Administration. (2017). Advanced Avionics Handbook Chapter 4: Automated Flight Control. Retrieved from [https://www.faa.gov/regulations\\_policies/handbooks\\_manuals/aviation/advanced\\_avionics\\_handbook/media/aah\\_ch04.pdf](https://www.faa.gov/regulations_policies/handbooks_manuals/aviation/advanced_avionics_handbook/media/aah_ch04.pdf)

- Federal Aviation Administration. (2012). Fair Treatment of Experienced Pilots Act (The Age 65 Law) Information, Questions and Answers. Retrieved from [https://www.faa.gov/other\\_visit/aviation\\_industry/airline\\_operators/airline\\_safety/info/all\\_infos/media/age65\\_qa.pdf](https://www.faa.gov/other_visit/aviation_industry/airline_operators/airline_safety/info/all_infos/media/age65_qa.pdf)
- Federal Motor Carrier Safety Administration. (2015). Interstate Truck Driver's Guide to Hours of Service. Retrieved from [https://www.fmcsa.dot.gov/sites/fmcsa.dot.gov/files/docs/Drivers Guide to HOS 2015\\_508.pdf](https://www.fmcsa.dot.gov/sites/fmcsa.dot.gov/files/docs/Drivers%20Guide%20to%20HOS%202015_508.pdf)
- Fernandes, P., & Nunes, U. (2010). Platooning of autonomous vehicles with intervehicle communications in SUMO traffic simulator. *IEEE Conference on Intelligent Transportation Systems, Proceedings, ITSC*, 1313–1318. <https://doi.org/10.1109/ITSC.2010.5625277>
- Fichter, K. (2017, May 18). *IEEE VTS Connected & Autonomous Vehicles Summer School*. Worcester, MA: Worcester Polytechnic Institute.
- Flämig, H. (2016). Autonomous Vehicles and Autonomous Driving in Freight Transport. In M. Maurer, J. C. Gerdes, H. Winner, & B. Lenz (Eds.), *Autonomous Driving: Technical, Legal and Social Aspects* (pp. 365–385). Springer Open. [https://doi.org/10.1007/978-3-662-48847-8\\_18](https://doi.org/10.1007/978-3-662-48847-8_18)
- Forrest, A., & Konca, M. (2007). Autonomous Cars and Society. *System*, 1609(508), 53. Retrieved from <http://www.wpi.edu/Pubs/E-project/Available/E-project-043007-205701/unrestricted/IQPOVP06B1.pdf>
- Freightliner. (2015, May 5). Freightliner Inspiration Truck Receives Autonomous Vehicle Licensing from Nevada DMV. *India Automobile News*.



- Frey, C. B., & Osborne, M. A. (2017). The future of employment: How susceptible are jobs to computerisation? *Technological Forecasting & Social Change*, 114, 254–280.  
<https://doi.org/10.1016/j.techfore.2016.08.019>
- Go Boston 2030. (2017). Go Boston 2030: Vision and Action Plan.
- Gold, C., Korber, M., Lechner, D., & Bengler, K. (2016). Takeover Performance in complex Traffic Situations: The Role of Traffic Density. *Human Factors*, 58(4), 642–652.  
Retrieved from <http://journals.sagepub.com/doi/pdf/10.1177/0018720816634226>
- Guerra, E. (2015). When Autonomous Cars Take to the Road. Retrieved September 21, 2017, from <https://www.planning.org/planning/2015/may/autonomouscars.htm>
- Guerra, E. (2016). Planning for Cars That Drive Themselves: Metropolitan Planning Organizations, Regional Transportation Plans, and Autonomous Vehicles. *Journal of Planning Education and Research*, 36(2), 210–224.  
<https://doi.org/10.1177/0739456X15613591>
- Haboucha, C. J., Ishaq, R., & Shiftan, Y. (2016). User preferences regarding autonomous vehicles. *Transportation Research Part C: Emerging Technologies*, 78, 37–49.  
Retrieved from  
[https://ac.els-cdn.com/S0968090X17300177/1-s2.0-S0968090X17300177-main.pdf?\\_tid=83263e3a-a47d-11e7-9888-00000aab0f27&acdnat=1506624644\\_43a859e736922ef9c95e50c2f42f9282](https://ac.els-cdn.com/S0968090X17300177/1-s2.0-S0968090X17300177-main.pdf?_tid=83263e3a-a47d-11e7-9888-00000aab0f27&acdnat=1506624644_43a859e736922ef9c95e50c2f42f9282)
- Hall, K. (2017, September 13). Testimony for Senate Commerce Hearing on Transportation Innovation: Automated Trucks and Our Nation’s Highways. Senate Committee on Commerce, Science, and Transportation.
- Hall, M. (2014). Forget self-driving Google cars, Australia has self-driving trucks. Retrieved from

<http://www.theage.com.au/it-pro/business-it/forget-selfdriving-google-cars-australia-has-selfdriving-trucks-20141020-118o47.html>

Harper, C. D., Hendrickson, C. T., Mangones, S., & Samaras, C. (2016). Estimating potential increases in travel with autonomous vehicles for the non-driving, elderly and people with travel-restrictive medical conditions. *Transportation Research Part C: Emerging Technologies*, 72, 1–9. <https://doi.org/10.1016/j.trc.2016.09.003>

Havemann, J. (2009). The Financial Crisis of 2008. In *Encyclopædia Britannica*. Encyclopædia Britannica, Inc. Retrieved from <https://www.britannica.com/topic/Financial-Crisis-of-2008-The-1484264>

Hawes, C. (2017). New ATA Report Forecasts Steady Growth for Trucking Industry | Trucks.com. Retrieved November 15, 2017, from <https://www.trucks.com/2017/07/19/trucking-industry-steady-growth/>

Hawkins, A. (2017). These nine states will serve as testing grounds for self-driving cars. Retrieved December 16, 2017, from <https://www.theverge.com/2017/1/23/14357564/dot-self-driving-car-testing-sites-nine-states>

Hayes, B. (2011). Leave the Driving to It. *American Scientist*, 99(5), 362–366. Retrieved from <http://www.jstor.org/stable/pdf/23019343.pdf?refreqid=search%3A437e55d98eac9753f10b376e95ac1558>

Hernandez, S. G. (2017, September 13). Testimony for Senate Commerce Hearing on Transportation Innovation: Automated Trucks and Our Nation's Highways. Senate Committee on Commerce, Science, and Transportation.

- Hersman, D. (2017, September 13). Testimony for Senate Commerce Hearing on Transportation Innovation: Automated Trucks and Our Nation's Highways. Senate Committee on Commerce, Science, and Transportation.
- Heutger, M., & Kückelhaus, M. (2014). SELF-DRIVING VEHICLES IN LOGISTICS. Retrieved from [http://www.dhl.com/content/dam/downloads/g0/about\\_us/logistics\\_insights/dhl\\_self\\_driving\\_vehicles.pdf](http://www.dhl.com/content/dam/downloads/g0/about_us/logistics_insights/dhl_self_driving_vehicles.pdf)
- Heutger, M., & Kückelhaus, M. (2014). SELF-DRIVING VEHICLES IN LOGISTICS A DHL perspective on implications and use cases for the logistics industry 2014, 39. Retrieved from [http://www.dhl.com/content/dam/downloads/g0/about\\_us/logistics\\_insights/dhl\\_self\\_driving\\_vehicles.pdf](http://www.dhl.com/content/dam/downloads/g0/about_us/logistics_insights/dhl_self_driving_vehicles.pdf)
- Hevelke, A., & Nida-Rumelin, J. (2015). Responsibility for Crashes of Autonomous Vehicles: An Ethical Analysis. *Science and Engineering Ethics*, 21(3), 619–630. <https://doi.org/10.1007/s11948-014-9565-5>
- Highway Loss Data Institute. (2010). New estimates of benefits of crash avoidance features on passenger vehicles. Retrieved March 10, 2018, from <http://www.iihs.org/iihs/sr/statusreport/article/45/5/2>
- Hohenberger, C., Spörrle, M., & Welp, I. M. (2016). How and why do men and women differ in their willingness to use automated cars? The influence of emotions across different age groups. *Transportation Research Part A: Policy and Practice*. <https://doi.org/10.1016/j.tra.2016.09.022>
- Holley, P. (2018, March 9). Waymo's self-driving trucks will arrive on Georgia roads next week. *Washington Post*, p. 1. Retrieved from

- [https://www.washingtonpost.com/news/innovations/wp/2018/03/09/waymos-self-driving-trucks-will-arrive-on-georgia-roads-next-week/?utm\\_term=.4a706a13055f](https://www.washingtonpost.com/news/innovations/wp/2018/03/09/waymos-self-driving-trucks-will-arrive-on-georgia-roads-next-week/?utm_term=.4a706a13055f)
- Howard, R. W. (1973). AUTOMATIC FLIGHT CONTROLS IN FIXED WING AIRCRAFT: THE FIRST 100 YEARS. *Aeronautical Journal*, 533–562.
- Hu, L., & Schneider, R. J. (2017). Different ways to get to the same workplace: How does workplace location relate to commuting by different income groups?  
<https://doi.org/10.1016/j.tranpol.2017.07.009>
- INRIX, Ash, A., Pushue, B., & Weiser, B. (n.d.). INRIX Identifies Top U.S. Cities for Shared Highly Autonomous Vehicle Deployment. Kirkland, WA.
- International Transport Forum. (2017). Managing the Transition to Driverless Road Freight Transport. Retrieved from  
<https://www.itf-oecd.org/sites/default/files/docs/managing-transition-driverless-road-freight-transport.pdf>
- Kilcarr, S. (2017). Trucking ignores technology at its own peril. *Fleet Owner*; Overland Park.
- Kilcarr, S. (2017). The automation of work: How will trucking cope? *Fleet Owner*.
- Kim, Y. J., Kim, K., & Lee, S. (2017). The rise of technological unemployment and its implications on the future macroeconomic landscape. *Futures*, 87, 1–9.  
<https://doi.org/10.1016/j.futures.2017.01.003>
- Kitroeff, N., & Mahan, G. (2017, March 17). Wages rise on California farms. Americans still don't want the job. *Los Angeles Times*. Retrieved from  
<http://www.latimes.com/projects/la-fi-farms-immigration/>

- König, M., & Neumayr, L. (2017). Users' resistance towards radical innovations: The case of the self-driving car. *Transportation Research Part F: Traffic Psychology and Behaviour*. <https://doi.org/10.1016/j.trf.2016.10.013>
- Korzep, K. (2010). The future of technology and the effect it may have on replacing human jobs. *Technology and Health Care*. <https://doi.org/10.3233/THC-2010-0592>
- KPMG. (2015). Automobile insurance in the era of autonomous vehicles: survey results.
- Krueger, R., Rashidi, T. H., & Rose, J. M. (2016). Preferences for shared autonomous vehicles. *Transportation Research Part C: Emerging Technologies*. <https://doi.org/10.1016/j.trc.2016.06.015>
- Kyriakidis, M., Happee, R., & De Winter, J. C. F. (2015). Public opinion on automated driving: Results of an international questionnaire among 5000 respondents. *Transportation Research Part F: Traffic Psychology and Behaviour*. <https://doi.org/10.1016/j.trf.2015.04.014>
- Le Vine, S., Zolfaghari, A., & Polak, J. (2015). Autonomous cars: The tension between occupant experience and intersection capacity. *Transportation Research Part C: Emerging Technologies*. <https://doi.org/10.1016/j.trc.2015.01.002>
- Lin, P.-S., Wang, Z., & Guo, R. (2016). Impact of Connected Vehicles and Autonomous Vehicles on Future Transportation. In *Bridging the East and West*. <https://doi.org/10.1061/9780784479810.006>
- Lindeman, T. (n.d.). Autonomous Semis Could Help Solve Trucking's Major Labor Shortage - Motherboard. Retrieved February 14, 2018, from [https://motherboard.vice.com/en\\_us/article/paq59y/autonomous-trucks-could-help-solve-truckings-major-labor-shortage-embark-tesla-uber-daimler](https://motherboard.vice.com/en_us/article/paq59y/autonomous-trucks-could-help-solve-truckings-major-labor-shortage-embark-tesla-uber-daimler)

- Litman, T. A. (2017). Autonomous Vehicle Implementation Predictions: Implications for Transport Planning. Traffic Technology International. Retrieved from [www.vtpi.org/AVIP\\_TTI\\_Jan2014.pdf](http://www.vtpi.org/AVIP_TTI_Jan2014.pdf)
- Lu, Z., Du, R., Dunham-Jones, E., Park, H., & Crittenden, J. (2017). Data-enabled public preferences inform integration of autonomous vehicles with transit-oriented development in Atlanta. Cities. <https://doi.org/10.1016/j.cities.2017.01.004>
- Maciag, M. (2017). The Cities Where Autonomous Vehicles Would Be Most Practical. Retrieved September 28, 2017, from <http://www.governing.com/topics/transportation-infrastructure/gov-autonomous-vehicles-cities.html>
- Madrigal, A. (2018). Could Self-Driving Trucks Be Good for Truckers? Retrieved February 14, 2018, from <https://www.theatlantic.com/technology/archive/2018/02/uber-says-its-self-driving-trucks-will-be-good-for-truckers/551879/>
- Mania, K., Jadav, B., Pujari, A., & Khandare, A. (n.d.). Automation in Farming Industry. IOSR Journal of Computer Engineering. Retrieved from <http://www.iosrjournals.org/iosr-jce/papers/Conf.17014-2017/Volume-2/14.68-72.pdf?id=7557>
- Marsh. (2017). From mechanical to smart devices: Trucking's one-way street.
- Marsh, A. (2017). From mechanical to smart devices: Trucking's one-way street. Fleet Owner; Overland Park.
- McGee, M. (n.d.). Air Transport Pilot Supply and Demand: Current State and Effects of Recent Legislation. Retrieved from

[https://www.rand.org/content/dam/rand/pubs/rgs\\_dissertations/RGSD300/RGSD351/RAND\\_RGSD351.pdf](https://www.rand.org/content/dam/rand/pubs/rgs_dissertations/RGSD300/RGSD351/RAND_RGSD351.pdf)

- McNally, S. (2017). ATA - ATA Truck Tonnage Index Fell 6.2% in December. American Trucking Associations. Retrieved from <http://www.trucking.org/article/ATA-Truck-Tonnage-Index-Fell-6.2%25-in-December>
- Meyer, J. (2016). Impact of autonomous vehicles on the accessibility in Switzerland. *Arbeitsberichte Verkehrs- Und Raumplanung*.
- Meyer, J., Becker, H., Bosch, P. M., & Axhausen, K. W. (2017). Autonomous vehicles: The next jump in accessibilities? *Research In Transportation Economics*, 62, 80–91. <https://doi.org/10.1016/j.retrec.2017.03.005>
- Mitchell, D., Claris, S., & Edge, D. (2016). Human-Centered Mobility: A New Approach to Designing and Improving Our Urban Transport Infrastructure. *Engineering*, 2, 33–36. <https://doi.org/10.1016/J.ENG.2016.01.030>
- Mohan, G. (2017, July 21). As California's labor shortage grows, farmers race to replace workers with robots. *Los Angeles Times*. Retrieved from <http://www.latimes.com/projects/la-fi-farm-mechanization/>
- Mulligan, C. (2015). The Automation of Agriculture, Part I. Retrieved December 6, 2017, from <https://www.fcc-fac.ca/en/ag-knowledge/ag-economics/the-automation-of-agriculture-part-one.html>
- Mulligan, C. (2015). The Automation of Agriculture, Part II: Farming with Robots. Retrieved December 6, 2017, from <https://www.fcc-fac.ca/en/ag-knowledge/ag-economics/the-automation-of-agriculture-part-II-farming-with-robots.html>

- Mulligan, C. (2015). The Automation of Agriculture, Part III: Observations and Conclusions. Retrieved December 6, 2017, from <https://www.fcc-fac.ca/en/ag-knowledge/ag-economics/the-automation-of-agriculture-observations-and-conclusions-part-iii.html>
- National Coordination Office for Space-Based Positioning Navigation and Timing. (2016). GPS Applications: Agriculture. Retrieved December 6, 2017, from <https://www.gps.gov/applications/agriculture/>
- NHTSA. (2017). Automated Driving Systems 2.0: A Vision For Safety. U.S. Department of Transportation.
- NHTSA. (2016). Federal Automated Vehicles Policy: Accelerating the Next Revolution In Roadway Safety. U.S. Department of Transportation, (September), 116. <https://doi.org/12507-091216-v9>
- Padleckas, H. (2011). Conventional 18-Wheeler Truck Diagram. Retrieved from [https://commons.wikimedia.org/wiki/File:Conventional\\_18-wheeler\\_truck\\_diagram.svg](https://commons.wikimedia.org/wiki/File:Conventional_18-wheeler_truck_diagram.svg)
- Peterson, A. (2015, June 22). Google didn't lead the self-driving vehicle revolution. John Deere did. The Washington Post. Retrieved from [https://www.washingtonpost.com/news/the-switch/wp/2015/06/22/google-didnt-lead-the-self-driving-vehicle-revolution-john-deere-did/?utm\\_term=.1d551c7a8d94](https://www.washingtonpost.com/news/the-switch/wp/2015/06/22/google-didnt-lead-the-self-driving-vehicle-revolution-john-deere-did/?utm_term=.1d551c7a8d94)
- Pinto, C. (2012). How autonomous vehicle policy in california and nevada addresses technological and non-technological liabilities. *Intersect: The Stanford Journal of Science, Technology ....*
- PwC Strategy&. (2016). Truck Study 2016: The Era of Digitized Trucking. PwC. Retrieved from <https://mackinstitute.wharton.upenn.edu/>



- Rafter, M. (n.d.). Feds Say Truckers Over-Counted, Autonomous Tech Threat Overstated. Retrieved February 14, 2018, from <https://www.trucks.com/2018/02/01/truckers-autonomous-tech-threat-overstated/>
- Renner, D. A. (1998). Cross-country Truck Drivers: A Vulnerable Population. *Nursing Outlook*, 46(4), 164–168.
- Ring, T. (2015). Connected cars - The next target for hackers. *Network Security*. [https://doi.org/10.1016/S1353-4858\(15\)30100-8](https://doi.org/10.1016/S1353-4858(15)30100-8)
- Rivera, E. (2017). Long-Distance Freight Trucking in the US. IBIS World. Retrieved from <http://clients1.ibisworld.com/reports/us/industry/default.aspx?entid=1150>
- Rivera, E. (2017). Local Freight Trucking in the US. IBIS World. Retrieved from <http://clients1.ibisworld.com/reports/us/industry/keystatistics.aspx?indid=1149>
- Rivera, E. (2014). Long-Distance Freight Trucking in the US. IBIS World. Retrieved from [http://btiweb.serveronline.net/Documents/IBIS World Reports/48412 Long-Distance Freight Trucking in the US industry report \(2\).pdf](http://btiweb.serveronline.net/Documents/IBIS World Reports/48412 Long-Distance Freight Trucking in the US industry report (2).pdf)
- Rodoulis, S. (2014). The Impact of Autonomous Vehicles on Cities. *Journeys - Sharing Urban Transport Solutions*.
- Roland Berger Strategy Consultants GmbH. (2015). On the Road Toward the Autonomous Truck: Opportunities for OEMs and Suppliers. Retrieved from [https://www.rolandberger.com/en/Publications/pub\\_autonomous\\_truck.html](https://www.rolandberger.com/en/Publications/pub_autonomous_truck.html)
- Ross, P. E. (2015). Robo-Trucks Come to Canada's Oil Sands. Retrieved November 15, 2017, from <https://spectrum.ieee.org/cars-that-think/transportation/self-driving/robotrucks-come-to-canadas-oil-sands>

- Sanctis, M. (2017, September 17). Navistar CEO sees role for drivers with self-driving trucks. Springfield News-Sun, Ohio.
- Scheck, W. (2017). Lawrence Sperry: Genius on Autopilot | HistoryNet. Retrieved March 12, 2018, from <http://www.historynet.com/lawrence-sperry-autopilot-inventor-and-aviation-innovator.htm>
- Schellekens, M. (2015). Self-driving cars and the chilling effect of liability law. Computer Law & Security Review. <https://doi.org/10.1016/j.clsr.2015.05.012>
- Schellekens, M. (2016). Car hacking: Navigating the regulatory landscape. <https://doi.org/10.1016/j.clsr.2015.12.019>
- Schrank., D., Eisele., B., Lomax., T., & Bak., J. (2015). 2015 Urban Mobility Scorecard. Texas A&M Transportation Institute, 39(August), 5. <https://doi.org/DTRT06-G-0044>
- Sean Samuel Kilcarr. (2015). The price tag for autonomous trucks still unclear. Retrieved January 19, 2018, from <http://www.fleetowner.com/technology/price-tag-autonomous-trucks-still-unclear>
- Service, U. S. P. (2018). USPS Shipping Price List. Retrieved January 19, 2018, from [https://pe.usps.com/text/dmm300/Notice123.htm#\\_c031](https://pe.usps.com/text/dmm300/Notice123.htm#_c031)
- Sheehan, B., Murphy, F., Ryan, C., Mullins, M., & Liu, H. Y. (2017). Semi-autonomous vehicle motor insurance: A Bayesian Network risk transfer approach. Transportation Research Part C: Emerging Technologies. <https://doi.org/10.1016/j.trc.2017.06.015>
- Shiers, W., & Barnett, C. (2016, June). Automatic for the People. Commercial Motor, 38–41.
- Shladover, S. E. (2015). Road Vehicle Automation History, Opportunities and Challenges.

- Short, J., & Murray, D. (2016, October). Identifying Autonomous Vehicle Technology Impacts on the Trucking Industry. American Transportation Research Institute. Retrieved from <http://atri-online.org/wp-content/uploads/2016/11/ATRI-Autonomous-Vehicle-Impacts-11-2016.pdf>
- Sparrow, A. R., Mollicone, D. J., Kan, K., Bartels, R., Satterfield, B. C., Riedy, S. M., ... Van Dongen, H. P. A. (2016). Naturalistic field study of the restart break in US commercial motor vehicle drivers: Truck driving, sleep, and fatigue. *Accident Analysis and Prevention*, 93, 55–64. <https://doi.org/10.1016/j.aap.2016.04.019>
- Sparrow, R., & Howard, M. (2017). When human beings are like drunk robots: Driverless vehicles, ethics, and the future of transport. *Transportation Research Part C: Emerging Technologies*, 80, 206–215. <https://doi.org/10.1016/j.trc.2017.04.014>
- Spear, C. (2017, September 13). Testimony for Senate Commerce Hearing on Transportation Innovation: Automated Trucks and Our Nation’s Highways. Senate Committee on Commerce, Science, and Transportation, pp. 1–8.
- Stenquist, P. (2014). In Self-Driving Cars, a Potential Lifeline for the Disabled - The New York Times. Retrieved September 21, 2017, from <https://www.nytimes.com/2014/11/09/automobiles/in-self-driving-cars-a-potential-life-line-for-the-disabled.html>
- Thune, J., & Peters, G. (2017, September 13). Senate Commerce Hearing on Transportation Innovation: Automated Trucks and Our Nation’s Highways. Senate Committee on Commerce, Science, and Transportation.
- Torrey, W. F., & Murray, D. (2014). An Analysis of the Operational Costs of Trucking: 2014 Update.

- Torrey, W. F., & Murray, D. (2014). An Analysis of the Operational Costs of Trucking: 2014 Update.
- Truckinginfo. (2017). Volvo Demonstrates Autonomous Truck Technology. Retrieved March 4, 2018, from <http://www.truckinginfo.com/channel/equipment/news/story/2017/11/volvo-demonstrates-autonomous-truck-technology.aspx>
- U.S. Energy Information Administration. (2017). Study of the Potential Energy Consumption Impacts of Connected and Automated Vehicles. Retrieved from [https://www.eia.gov/analysis/studies/transportation/automated/pdf/automated\\_vehicles.pdf](https://www.eia.gov/analysis/studies/transportation/automated/pdf/automated_vehicles.pdf)
- U.S. Global ETFs. (2017). Pilot Shortage: A Blessing in Disguise? Retrieved March 10, 2018, from <https://www.usglobaletf.com/insights/pilot-shortage-a-blessing-in-disguise/>
- US Department of Transportation. (2016). Accelerating the Next Revolution in Roadway Safety. <https://doi.org/12507-091216-v9>
- Vehicle Valuation Services, I. (n.d.). Truck/Tractor & Trailer Glossary of Terms. Oakbrook Terrace, IL: Vehicle Valuation Services, Inc. Retrieved from <http://www.vvsi.com/Assets/training-guides/Glossary-of-Terms-4.pdf>
- Vellinga, N. E. (2017). From the testing to the deployment of self-driving cars: Legal challenges to policymakers on the road ahead ARTICLE IN PRESS ScienceDirect. Computer Law & Security Review: The International Journal of Technology Law and Practice. <https://doi.org/10.1016/j.clsr.2017.05.006>
- Von Roessing, R. (2016). Highwaymen to hackers. Computer Fraud and Security. [https://doi.org/10.1016/S1361-3723\(16\)30026-4](https://doi.org/10.1016/S1361-3723(16)30026-4)

- Wadud, Z. (2017). Fully automated vehicles: A cost of ownership analysis to inform early adoption. *Transportation Research Part A: Policy and Practice*.  
<https://doi.org/10.1016/j.tra.2017.05.005>
- Wadud, Z. (2017). Fully automated vehicles: A cost of ownership analysis to inform early adoption. *Transportation Research Part A: Policy and Practice*.  
<https://doi.org/10.1016/j.tra.2017.05.005>
- Wakabayashi, D. (2018, March 6). Uber's Self-Driving Trucks Hit the Highway, but Not Local Roads. *New York Times*, p. 1. Retrieved from  
<https://www.nytimes.com/2018/03/06/technology/uber-self-driving-trucks.html>
- Wall, R. W., Bennett, J., Eis, G., Lichy, K., & Owings, E. (2002). Creating a low-cost autonomous vehicle. In *IECON Proceedings (Industrial Electronics Conference)*.  
<https://doi.org/10.1109/IECON.2002.1182894>
- Whelchel, R. J. (1993). Technology and Jobs. *IEEE Technology and Society Magazine*.  
<https://doi.org/10.1109/44.216773>
- Wise, D. (2016). VEHICLE CYBERSECURITY: DOT and Industry Have Efforts Under Way, but DOT Needs to Define Its Role in Responding to a Real-world Attack. United States Government Accountability Office.
- Woods, R. (2016, October). The Rise of Autonomous Tech. *Air Cargo World Magazine*.
- Wunderlin, A. (2017). the future of self driving cars. *Food Logistics*.
- Wunderlin, A. (2017, January). The Future of Self-Driving Vehicles. *Food Logistics*.
- Zmud, J. P., & Sener, I. N. (2017). Towards an Understanding of the Travel Behavior Impact of Autonomous Vehicles. *Transportation Research Procedia*, 25(0), 2500–2519. <https://doi.org/10.1016/j.trpro.2017.05.281>

- Zmud, J., Ecola, L., Phelps, P., & Feige, I. (2013). The Scenarios. In *The Future of Mobility: Scenarios for the United States in 2030* (pp. 26–49). RAND Corporation. Retrieved from <http://www.jstor.org/stable/pdf/10.7249/j.ctt5hhw3n.9.pdf?refreqid=search%3A36ab1849af80352ac396fabf2ed5d884>
- Demographic Shifts: Shaping the Future of Car Ownership - Knowledge@Wharton. (2017). Retrieved September 14, 2017, from <http://knowledge.wharton.upenn.edu/article/demographic-shifts-shaping-future-car-ownership/>
- H.R. 3388 — 115th Congress: SELF DRIVE Act (2017). United States House of Representatives. Retrieved from <https://www.gpo.gov/fdsys/pkg/BILLS-115hr3388rfs/pdf/BILLS-115hr3388rfs.pdf>
- Autonomous Tractors- The Future of Farming? (2017). Retrieved December 6, 2017, from <http://www.bigag.com/topics/equipment/autonomous-tractors-future-farming/>
- Morgan Stanley — the Economic Benefits of Driverless Cars. (2013). Retrieved January 20, 2018, from <https://robotenomics.com/2014/02/26/morgan-stanley-the-economic-benefits-of-driverless-cars/>
- How Canada's Oilsands are Paving the Way for Driverless Trucks--and the Threat of Big Layoffs. (n.d.). Calgary Herald. Retrieved from <http://calgaryherald.com/business/energy/how-canadas-oilsands-are-paving-the-way-for-driverless-trucks-and-the-threat-of-big-layoffs>